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Volume III. Agricultural Research Study

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16. ABSTRACT

The Lubbock Land Treatment System Research and Demonstration Project, funded by Congress in 1978 (H.R. 9375), was designed to address the various issues concerning the use of slow rate land application of municipal wastewater. The project involved the 1) physical expansion of an overloaded 40-year old Lubbock slow rate land treatment system; 2) characterization of the chemical, biological and physical conditions of the ground water, soils and crops prior to and during irrigation with secondary treated municipal wastewater; 3) evaluation of the health effects associated with the slow rate land application of secondary effluent and 4) assessment of the effects of hydraulic, nutrient and salt mass loadings on crops, soil and percolate. This volume details the agricultural research program conducted at both the old farm with reduced hydraulic loading and the new farm which previously had been operated as a dry land farm.

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THE LUBBOCK LAND TREATMENT SYSTEM RESEARCH AND DEMONSTRATION PROJECT

VOLUME III

Agricultural Research Study

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DISCLAIMER

The information in this document has been funded in part by the United States Environmental Protection Agency under assistance agreement No. CS806204 to the Lubbock Christian College Institute of Water Research. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency was established to coordinate the administration of major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

The U.S. Environmental Protection Agency's Office of Research and Development conducts this search through a nationwide network of research facilities. As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs including the development and demonstration of soil and other natural systems for the treatment and management of municipal wastewaters.

The slow rate land treatment process of municipal wastewaters uses the unsaturated soil profile and agricultural crops managed as the treatment media. The Lubbock Land Treatment System Research and Demonstration Program, funded by Congress in 1978 (H.R. 9575) was designed to address the various issues limiting the use of slow rate land application of municipal wastewater. The project involved expansion of the Lubbock Land Treatment System to 2,967 hectares; characterization of the chemical, biological and physical condition of the ground water, soils and crops prior to and during irrigation with secondary treated municipal wastewater; and evaluation of the U.S. Environmental Protection Agency's design criteria for slow rate land application. Results demonstrate that, where such systems are correctly designed and operated, they can be cost effective alternatives for municipal sewage treatment at sites where conditions are favorable for low hydraulic loading combined with cropping practices.

This report contributes to the knowledge which is essential for the U.S. Environmental Protection Agency to meet requirements of environmental laws and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

Clinton W. Hall

Clinton W. Hall, Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

Prior to 1982, ground-water problems beneath the Gray farm which used wastewater produced by the City of Lubbock for crop irrigation may have resulted from the inability to properly manage the water and nutrient mass loadings imposed on the farm. Agricultural research activities were conducted to focus on crop management alternatives to minimize problems associated with high hydraulic, nutrient, and salt loading rates.

Agricultural studies showed that cotton and grain sorghum produced greater yields with increasing annual hydraulic loading rates up to 3 m.ha/ha.yr. The highest alfalfa yields were obtained in test plots irrigated with 365 and 434 cm.ha/ha.yr. The alfalfa test plots appeared to remove all nutrients applied in the wastewater stream. Salts were leached beyond 91 cm of soil in all plots receiving 60 cm.ha/ha/yr or greater.

Increasing the quantity of water applied to a crop tranports sodium salts deeper into the soil profile. Soybean seed and stalk analysis indicated leaching of sodium from the root zone commenced almost immediately at the 122 cm/yr hydraulic loading. At the 61 cm/yr loading, irrigation events must occur at intervals of two weeks or longer to promote leaching of sodium. Practically no leaching occurred even at the one application per eight weeks frequency at the effluent loading of 31 cm/yr.

Soybeans with a relatively shallow root system, produced highest yields with more frequent irrigation (i.e., one irrigation per week). Soybeans were unable to develop a deep root system to utilize deeper soil moisture during periods of water stress (one irrigation every four weeks or one irrigation every eight weeks); consequently, crop yields were reduced.

During long periods between irrigation events, the deep root system developed by grain sorghum enabled the plant to utilize available soil moisture and inorganic nitrogen at greater depths. Highest grain sorghum production was achieved in plots irrigated 61 and 122 cm/yr at application frequencies of once every four weeks and once every eight weeks.

The agricultural research studies were a portion of the Lubbock Land Treatment System Research and Demonstration Project which was conducted by

Lubbock Christian College Institute of Water Research (LCCIWR). This report was submitted in fulfillment of cooperative agreement CS8062040 by LCCIWR under primary sponsorship of the U.S. Environmental Protection Agency. The report presents a summary of research activities performed from June 1, 1982 through December 31, 1983. This work was completed on June 30, 1985.

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SECTION I

INTRODUCTION

Since the latter part of 1938 the effluent produced by the City of Lubbock's Southeast Water Reclamation Plant (SeWRP) has been reused for irrigation of crops grown on the Gray farm. Due to degradation of ground-water quality beneath the Gray farm, the Lubbock slow rate land treatment system was enlarged to include the 1478 ha Hancock farm in 1981 (Figure 1). The expanded land application system encompassed 2565 ha.

Ground-water problems beneath the Gray Farm were a direct result of the inability to properly manage the water and nutrient mass loadings imposed on the farm with the existing hydraulic storage and distribution system (George et al 1985). In general, slow rate wastewater reuse systems present potential water, nutrient and salt management problems to farm managers. Annual, seasonal, and diurnal variations in hydraulic and chemical mass loadings, in conjunction with varying climatic conditions, mandates that a manager employ the best agricultural practices to effectively reuse the resources present in the waste stream.

Minimum information exists defining water tolerance levels of various crops grown in the Southwest. In addition, design manuals (EPA 1981; Loehr et al 1979; and Texas Department of Water Resources (TDWR) design procedures fail to adequately define the impact of hydraulic application rates and frequency of application on salt management within the soil profile.

Agricultural research activities conducted at the Hancock farm focused on crop management to minimize problems associated with high hydraulic, nutrient, and salt loading rates. The specific objectives of the agricultural research were:

1. Evaluate the effect of hydraulic loading rates on various crops
2. Determine the effect of application rates and frequency of application on salt accumulation in soils and ultimate impact on crops

The Agricultural Research Studies were a portion of several areas of research conducted during the Lubbock Land Treatment System Research and

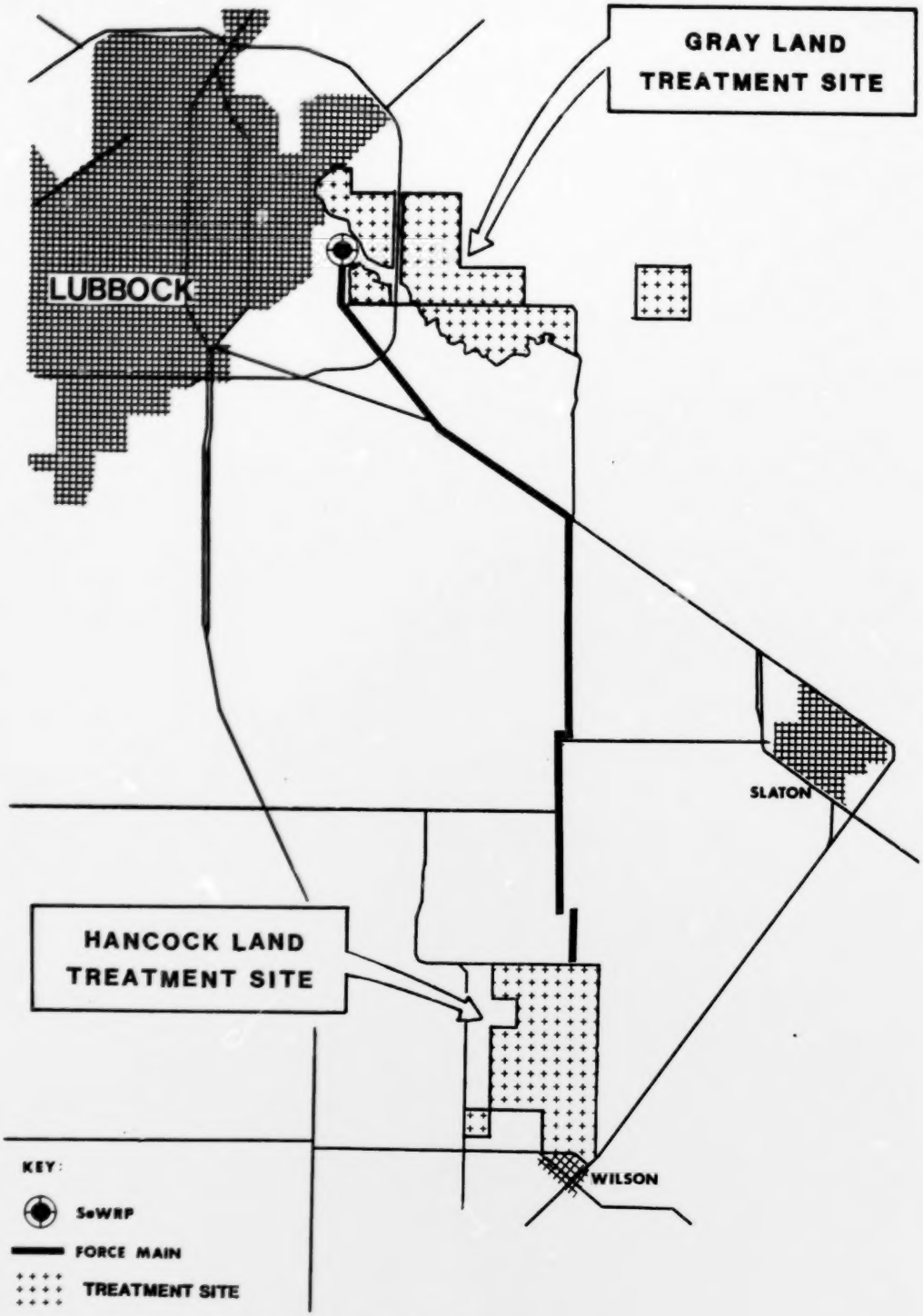


Figure 1. Lubbock Land Treatment System

Demonstration Project. The project involved the 1) physical expansion of the Lubbock Land Treatment System; 2) characterization of the chemical, biological and physical conditions of the ground water, soils and crops prior to and during irrigation with secondary treated municipal wastewater; 3) evaluation of the health effects associated with the slow rate land application of secondary effluent; and 4) assessment of the effects of hydraulic, nutrient and salt mass loadings on crops, soil, and percolate. In addition to the information presented in this document, results from the Lubbock Land Treatment Research and Demonstration Project are published in

1. Volume I: Demonstration/Hydrogeologic Study (George et al 1985)
2. Volume II: Percolate Investigation in the Root Zone (Ramsey and Sweazy 1985)
3. Volume IV: Lubbock Infection Surveillance Study (LISS)(Camann et al 1985)
4. Volume V: Executive Summary (George et al 1985)

SECTION 2

SUMMARY AND CONCLUSIONS

SUMMARY

Slow rate wastewater reuse systems present potential water, nutrient and salt management problems to farm managers. Annual, seasonal, and diurnal variations in hydraulic and chemical mass loadings, in conjunction with varying climatic conditions, mandate that a manager employ the best agricultural practices to effectively reuse the resources present in the waste stream.

Agricultural research activities at the Hancock farm focused on crop management to minimize problems associated with high hydraulic, nutrient, and salt loading rates. Based on the information obtained during this investigation, it was ascertained that annual hydraulic loading rates up to 3 m.ha/ha.yr did not adversely affect cotton, grain sorghum, and alfalfa crop production. Highest alfalfa yields were obtained in test plots irrigated with 365 and 434 cm.ha/ha.yr. Total dissolved solids and associated sodium salts were leached beyond 91 cm soil depth within plots irrigated with 61 cm of treated sewage per year or greater. Bermuda yields were limited by transport of macro and micro nutrients past the root zone.

Soybeans with a relatively shallow root system, produced highest yields with more frequent irrigation (i.e., one irrigation per week). Soybeans were unable to develop a deep root system to utilize deeper soil moisture during periods of water stress (one irrigation every four weeks or one irrigation every eight weeks); consequently, crop yields were reduced.

During long periods between irrigation events, the deep root system developed by grain sorghum enabled the plant to utilize available soil moisture and inorganic nitrogen at greater depths. Highest grain sorghum production was achieved in plots irrigated 61 and 122 cm/yr at application frequencies of once every four weeks and once every eight weeks.

Increasing the quantity of water applied to a crop transports sodium salts deeper into the soil profile. Soybean seed and stalk analysis indicated leaching of sodium from the root zone commenced almost immediately at the 122 cm/yr hydraulic loading. At the 61 cm/yr loading,

irrigation events must occur at intervals of two weeks or longer to promote leaching of sodium. Practically no leaching occurred even at the one application per eight weeks frequency at the effluent loading of 31 cm/yr. With the shorter growing season experienced in 1982, soybeans may have had a higher water consumption rate than the grain sorghum due to the crop's maturity. Higher water requirement of soybeans in conjunction with its shallow root system may have caused higher sodium accumulations in the upper 61 cm than observed in grain sorghum test plots.

CONCLUSIONS

Hydraulic Loading Study

1. Grain sorghum yields increased to a maximum of 5163 kg/ha with increases in annual hydraulic loading to approximately 3 m/yr.
2. Cotton lint production increased with greater hydraulic loadings. Highest cotton lint yields were 1300 to 1538 kg/ha at hydraulic loadings ranging from 122 cm/yr to 297 cm/yr.
3. Effluent treated alfalfa plots produced greater yields than freshwater control plots. During each alfalfa cropping period, plots irrigated with 365 and 434 cm of effluent per year achieved the highest crop yields.
4. Alfalfa production obtained from effluent irrigated plots receiving more than 137 cm/yr was greatest in June 1983.
5. Bermuda yield was independent of annual hydraulic loading.
6. Alfalfa utilized from 500 to 800 kg-N/ha.yr. Nitrogen fixation provided a source of nitrogen for alfalfa production in all effluent and ground water irrigated plots.
7. With the exception of soils within alfalfa test plots, inorganic nitrogen was transported deeper into the soil profile when annual hydraulic loadings exceeded 61 cm/yr. Natural nitrite plus nitrate lens existed at 61 to 122 cm depth within the soil profile. These lens were forced deeper into the profile by applying effluent at increasing rates.

8. Annual hydraulic loading rates greater than or equal to 137 cm/yr leached total dissolved solids and associated sodium salts through the soil profile.
9. Exchangeable sodium percentage (ESP) was less than 9 within the upper 61 cm of soil for test plots irrigated with less than 365 cm/yr. Alfalfa plots having 434 cm of wastewater applied in 1983 contained soils in the top 61 cm with ESP values of 9.4 to 9.6. In general, leaching of sodium through the profile associated with a high soil calcium concentration inhibited the development of severe sodic conditions in the soil.
10. Leaching of macro and micro nutrients past the root zone limited bermuda growth.
11. In general, crop production appeared to be limited by available phosphorus deficiencies in the soils.

Hydraulic Loading vs. Wastewater Application Frequency Study

1. Soybeans with a relatively shallow root system, produced highest yields with more frequent irrigation (i.e., one irrigation per week). Soybeans were unable to develop a deep root system to utilize deeper soil moisture or during periods of water stress (one irrigation every four weeks or one irrigation every eight weeks); consequently, crop yields were reduced.
2. During long periods between irrigation events, the deep root system developed by grain sorghum enabled the plant to utilize available soil moisture and inorganic nitrogen at greater depths. Highest grain sorghum production was achieved in plots irrigated 61 and 122 cm at application frequencies of once every four weeks and once every eight weeks.
3. Increasing the quantity of water applied to a crop transports sodium salts deeper into the soil profile. Soybean seed and stalk analysis indicated leaching of sodium from the root zone commenced almost immediately at the 122 cm/yr hydraulic loading. At the 61 cm/yr loading, irrigation events must occur at intervals of two

weeks or longer to promote leaching of sodium. Practically no leaching occurred even at the one application per eight weeks frequency at the effluent loading of 31 cm/yr.

4. Soybeans higher water requirement in conjunction with its shallow root system caused higher sodium accumulations in the upper 61 cm than observed in grain sorghum test plots.
5. Light, frequent loadings should be avoided during crop germination and emergence due to surface salt accumulation.
6. Symbiotic nitrogen fixation provided a portion of the nitrogen consumed by soybeans irrigated with 30 cm of effluent per year containing an average inorganic nitrogen concentration of 37.91 mg-N/l. Once the average nitrogen mass applied was 231 kg-N/ha.yr and greater, nitrogen fixation was inhibited.

SECTION 3

RECOMMENDATIONS

1. There exists a need to develop operation manuals specifically oriented to aid the land application site farm manager in determining the proper water, nutrient, and crop management schemes to best reuse wastewater.
2. An investigation is required to correlate the relationship of a crop's root system to percolate flow and quality. Furthermore, the study should determine the relationship between crop production; root development; hydraulic loading and application frequency and nutrient mass loading.
3. An in depth investigation is warranted to evaluate the impact of various crops on the retention of salts at various depths within the soil profile at specific hydraulic loading rates.
4. Simple mathematical expressions need to be developed to enable the farm manager to grossly predict the benefits and liabilities to the crop-soil-water matrix resulting from a selected farm management scheme.
5. A long term study is needed to determine if salt management within the soil profile is feasible utilizing a center pivot irrigation machine.

SECTION 4

RESEARCH APPROACH

GENERAL

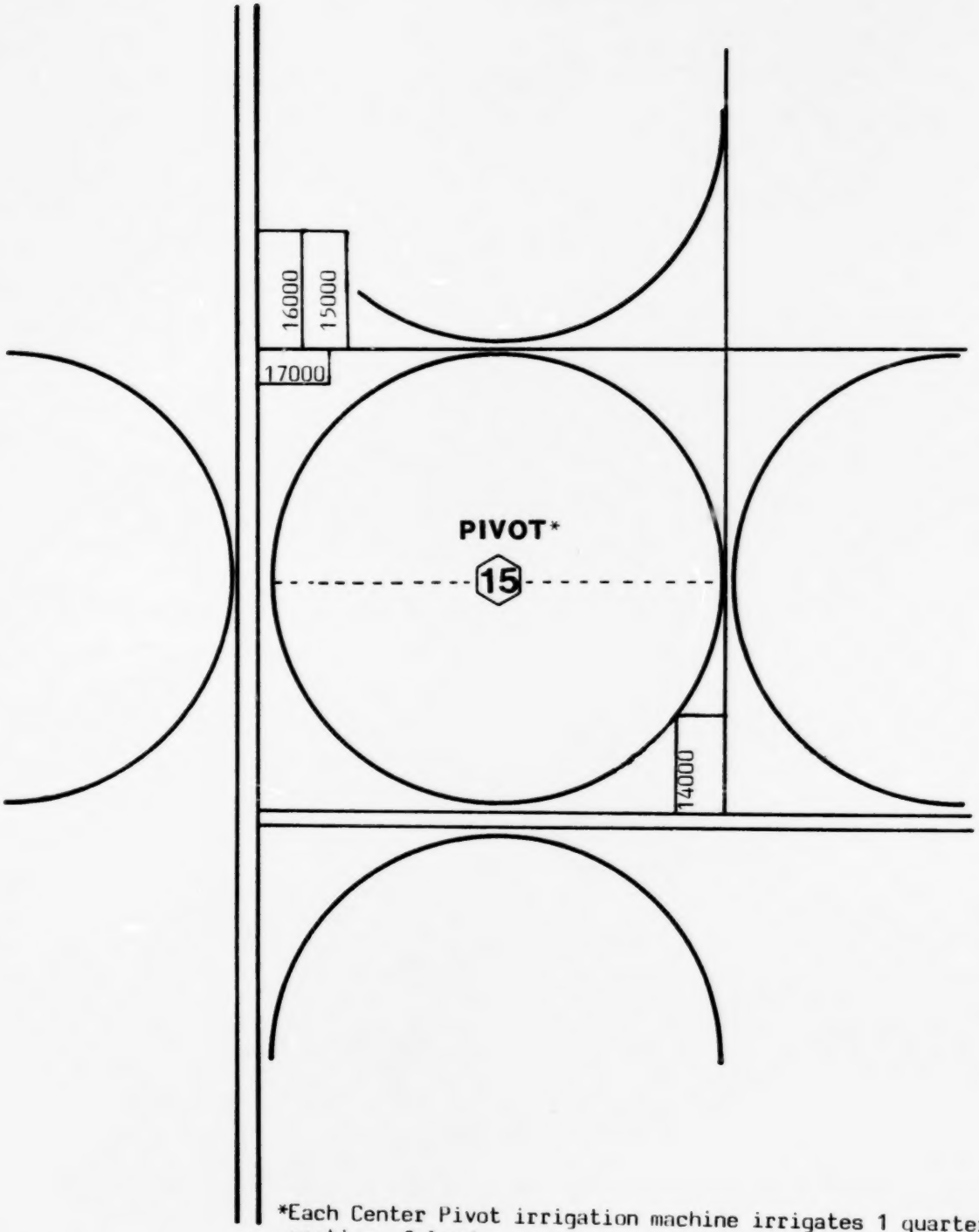
Experimental plots were established to evaluate the effect of hydraulic loading rates on various crops, soil, and percolate water. Similarly, research plots were designed and planted to determine the effect of application rates and frequency of application on salt accumulation in soils and the ultimate impact on crops. Figure 2 shows the layout of the Intensive Agricultural Research area.

The research plots were farmed in the same manner as the Hancock farm. Tractors, implements, planting times, row space, planting depth, cultivation, herbicides for weed control and pesticides for insect control similar to that used on the Hancock farm were used on the research plots.

Trial 14000 (Loading Rate Study, 0 to 122 cm/yr)

The wastewater discharge permit issued to the City of Lubbock by the Texas Department of Water Resources (TDWR) imposed a limit on the yearly amount of wastewater effluent applied to the Gray and Hancock farms of 122 cm (48 in). The hydraulic capacity of the force main and distribution system at the Hancock farm limited the maximum application rate to about 91 cm (3 ft)/yr. Major crops (i.e., cotton, milo, etc.) grown in the South Plains require 30 to 51 cm/yr (12 to 20 in/yr) to produce a good yield (Texas A & M Extension Service). Little information was available delineating the tolerance of crops to excessive irrigation. Trial 14000 was designed to evaluate the effect of applying 0 to 122 cm of effluent to cotton. The objectives of Trial 14000 were:

1. Determine the nutrient balance of cotton irrigated at nine different application rates ranging from zero to 122 cm/yr;
2. Determine the yield of crops grown at loading rates ranging from zero to 122 cm/yr;
3. Determine the effect of hydraulic loading rates (up to 122 cm/yr) on soil.



*Each Center Pivot irrigation machine irrigates 1 quarter section of land

Figure 2. Layout of Intensive Research Area at Hancock Farm

Design--

The cropping pattern for Trial 14000 is illustrated in Figure A.1. Four replicates were tested for each treatment. The total number of small plots (each plot 4.1 m x 13.7 m) was 36. Table 1 presents the irrigation schedule for Trial 14000.

Severe weather during May and June 1982 (i.e., hail and approximately 38 cm of precipitation) destroyed the emerging crop and prevented the completion of work on Trial 14000 for the 1982 growing season. Irrigation for 1983 was accomplished by flood irrigation.

In 1983, the total quantity of effluent irrigation for each test plot was accomplished; however, the irrigation schedule was shifted or delayed by spring weather and time of planting. Therefore, October scheduled irrigation occurred in November. Approximately 85 percent of the irrigation water in 1983 was derived from the reservoirs which contained an average total nitrogen concentration of 12.4 mg/l.

Trials 15000 and 16000 (High Loading Rate Study, 122 to 434 cm/yr)

Trial 15000 was an extension of Trial 14000. The investigation, however, not only considered the production of cotton and grain sorghum (Trial 15000) but also certain high nitrogen and water consuming crops such as alfalfa and bermuda (Trial 16000). The objectives of Trials 15000 and 16000 were:

1. Determine the nutrient balance of cotton and milo grain sorghum irrigated at application rates ranging from 152 to 343 cm/yr
2. Determine the nutrient balance of alfalfa and bermuda irrigated at application rates ranging from 152 to 465 cm/yr
3. Determine the yield of cotton and grain sorghum irrigated at loading rates ranging from 152 to 343 cm/yr
4. Determine the yield of alfalfa and bermuda subjected to 152 to 465 cm/yr irrigation
5. Determine the effect of hydraulic application rates (up to 111 cm/yr) on soil

TABLE 1. TRIAL 14000 COTTON IRRIGATION SCHEDULE (cm)

Total Irrigation (cm/yr)	Pre Plant (4 wks)	1st Bloom (2 wks)	Peak Bloom (2 wks)	Early Boll (4 wks)	Max Boll (4 wks)	1st Open Boll (4 wks)
0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.3	10.2	5.1	5.1	0.0	0.0	0.0
40.6	10.2	5.1	5.1	7.6	7.6	5.1
50.8	15.2	7.6	7.6	7.6	7.6	5.1
61.0	15.2	7.6	10.2	10.2	10.2	7.6
68.6	20.3	7.6	12.7	12.7	7.6	7.6
86.4	20.3	12.7	15.2	15.2	12.7	10.2
101.6	25.4	15.2	17.8	17.8	15.2	10.2
121.9	25.4	20.3	20.3	20.3	20.3	15.2

Design--

The layout for each Trial is presented in Figure A.2. Hydraulic loading rates employed in Trial 15000 were 122 cm/yr (4 ft/yr) to 287 cm/yr (9.7 ft/yr).

In addition to the loading rates used in Trial 15000, Trial 16000 included annual hydraulic rates of 365 cm/yr (12 ft/yr) and 434 cm/yr (14 ft/yr). These loading rates were designed to stress the system in order to determine maximum nutrient consumption by the crops, and maximum crop production.

Tables 2 and 3 provide the irrigation schedules for Trials 15000 and 16000, respectively. Irrigation of these plots was minimal until a crop stand was established. Once a stand was established, hydraulic loadings were increased to test water tolerance of crops and nutrient utilization.

Three fresh water control plots were established to differentiate crop yield suppression due to water loadings from suppression resulting from certain constituents in the wastewater effluent. Only one of the designed two replicates of the intermediate fresh water loadings (Treat-

TABLE 2. TRIAL 15000, 1983 IRRIGATION RATE BY MONTH (cm)

Treatment Number	Total Applied (cm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COTTON													
1	122.	0	8	0	8	0	30	30	30	0	8	0	5
2	183.	0	8	0	30	0	30	31	30	30	8	0	8
3	229.	0	8	8	30	0	30	43	43	43	8	8	8
4	297.	4	8	8	30	0	43	60	60	60	8	8	8
MILO													
1	122.	0	0	0	8	8	30	30	30	8	8	0	0
2	183.	0	8	0	30	8	30	43	30	8	8	0	0
3	229.	0	8	8	30	8	30	43	43	43	8	0	8
4	297.	4	8	8	30	8	44	60	60	60	15	0	0

TABLE 3. TRIAL 16000, 1983 IRRIGATION RATES BY MONTH (cm)

Treatment Number	Total Applied (cm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ALFALFA													
1	137.	8	0	15	0	22	23	23	23	15	0	8	0
2	198.	15	0	42	0	42	0	0	42	42	0	15	0
3	259.	8	0	30	0	46	30	46	30	46	15	8	0
4	305.	8	0	30	15	46	46	46	46	46	10	8	4
5	365.	8	0	30	30	46	46	61	61	46	25	8	4
6	434.	8	8	30	30	60	60	75	60	50	25	30	0
BERMUDA													
1	152.	0	0	0	15	24	24	42	24	15	0	0	8
2	198.	0	8	0	15	24	37	46	36	24	0	0	8
3	259.	0	8	0	30	30	46	46	46	30	15	0	8
4	305.	0	8	0	30	46	54	55	55	30	15	4	8
5	350.	0	8	0	30	55	55	63	63	30	30	8	8
6	396.	0	8	0	30	55	60	60	60	55	46	14	8

ments 10, 11, and 12) was maintained on the alfalfa. Approximately 11 hours were required to apply a 15.2 cm (6 in) of water to one of the plots. A cross contamination check was included in Trial 15000 (Treatment 5). Data obtained from Treatment 5 was to provide information concerning the lateral movement of water and nutrients into areas receiving water.

The alfalfa was initially watered with fresh water and sprinklers to get the best stand possible. Irrigation of seedlings with slightly brackish water [average Total Dissolved Solids (TDS) 1227 ppm] may have presented germination problems.

The row crops (grain sorghum and cotton) in Trial 15000 were planted and irrigated with little maintenance of irrigation ditches and virtually no field equipment work after crop establishment. The bermuda grass (Trial 16000) had to be harvested; therefore, periodically the irrigation ditches had to be closed to allow movement of harvesting equipment over the plots. After harvesting the grass, the ditches were reopened. Bermuda grew over the ditches and was incorporated into the ditch walls, which created leaks thereby increasing dike maintenance requirements. Alfalfa was harvested every 28 to 30 days. Each month from 12.7 to 58.8 cm of water had to be applied to the corresponding test plot per irrigation period.

Trial 17000 (Hydraulic Loading Rate vs Wastewater Application Frequency Study)

The average total dissolved solids (TDS) level in the wastewater applied to the Hancock farm was approximately 1200 mg/l. The major cation present in the waste stream was sodium. Sodium absorption ratio of the effluent was about 10. Accounting for alkalinity (average concentration 344 mg/l as $CaCO_3$), the adjusted SAR was approximately 22. Management of salt and water in wastewater reuse systems can be greatly affected by the crop grown, hydraulic loading and the frequency of wastewater applications. During 1982 and 1983, less than 0.66 m/yr (26 in/yr) of effluent was applied to the Hancock farm. Evapotransportation (ET) rates were normally greater than 127 cm/yr (50 in/yr). Average annual precipitation for the farm was 45 cm. Since ET values were greater than total hydraulic

loadings, accumulation of salts in the soil profile may have created serious problems with crop production. Two operational parameters which potentially will aid in the management of salts are the hydraulic loading rate and the frequency of application. The specific objectives of Trial 17000 were to:

1. Evaluate the effect of hydraulic loading rate on salt accumulation in the soils profile;
2. Determine what effect frequency of application has on salt accumulation in soils;
3. Assess to what extent crop yield is a function of hydraulic loading rate; and
4. Evaluate the response of crop production to different frequency of effluent application.

Design--

A solid set sprinkler irrigation system was employed in Trial 17000. This irrigation system reflected the method of irrigation used at the Hancock farm and most widely used throughout the United States.

Three nozzles spaced 6.1 m (20 ft) apart on 3.8 cm (1.5 in) PVC was moved through the field to attain the necessary irrigation. Crop samples, yield and soil samples were obtained from within the circular irrigated areas. A four frequency by three hydraulic loading rate matrix was established with two crops (soybeans and grain sorghum) (Table 4). Annual hydraulic loadings of 30, 61, and 122 cm were scheduled with applications made at one, two, four and eight week intervals. As the time intervals between applications increased, the amounts of water per application increased to maintain the scheduled yearly loadings. The test plot layout for Trial 17000 is shown in Figure A.3.

A centrifugal pump delivered 568 liter/min (150 gpm) at 207 kPa (30 psi) to the sprinkler system. Data was collected on Trial 17000 for one year.

SAMPLE COLLECTION AND ANALYSES

General

Irrigation water was derived from three sources (Figure 3): 1) dir-

TABLE 4. TREATMENT MATRIX HYDRAULIC LOADING RATE FOR SOYBEANS AND GRAIN SORGHUM IN TRIAL 17000

Application Frequency	Treatment* Code	Total Irrigation 30 cm/yr (12"/yr) Rate	Treatment Code	Total Irrigation 61 cm/yr (24"/yr) Rate	Treatment Code	Total Irrigation 122 cm/yr (48"/yr) Rate
		Irrigation Amount Per Frequency Period				
1 application per week	01	1.02 cm (0.4 in)	05	2.03 cm (0.8 in)	09	4.06 cm (1.6 in)
1 application per 2 weeks	02	2.03 cm (0.8 in)	06	4.06 cm (1.6 in)	10	8.13 cm (3.2 in)
1 application per 4 weeks	03	4.6 cm (1.6 in)	07	8.13 cm (3.2 in)	11	16.26 cm (6.4 in)
1 application per 8 weeks	04	8.13 cm (3.2 in)	08	16.26 cm (6.4 in)	12	32.51 cm (12.8 in)

*Treatment Code -- Code used to designate application frequency and hydraulic loading for hydraulic loading rates in Trial 17000. The same treatment codes are used in the test plot layout (Figure A.3) to show which subplots receive which treatments.

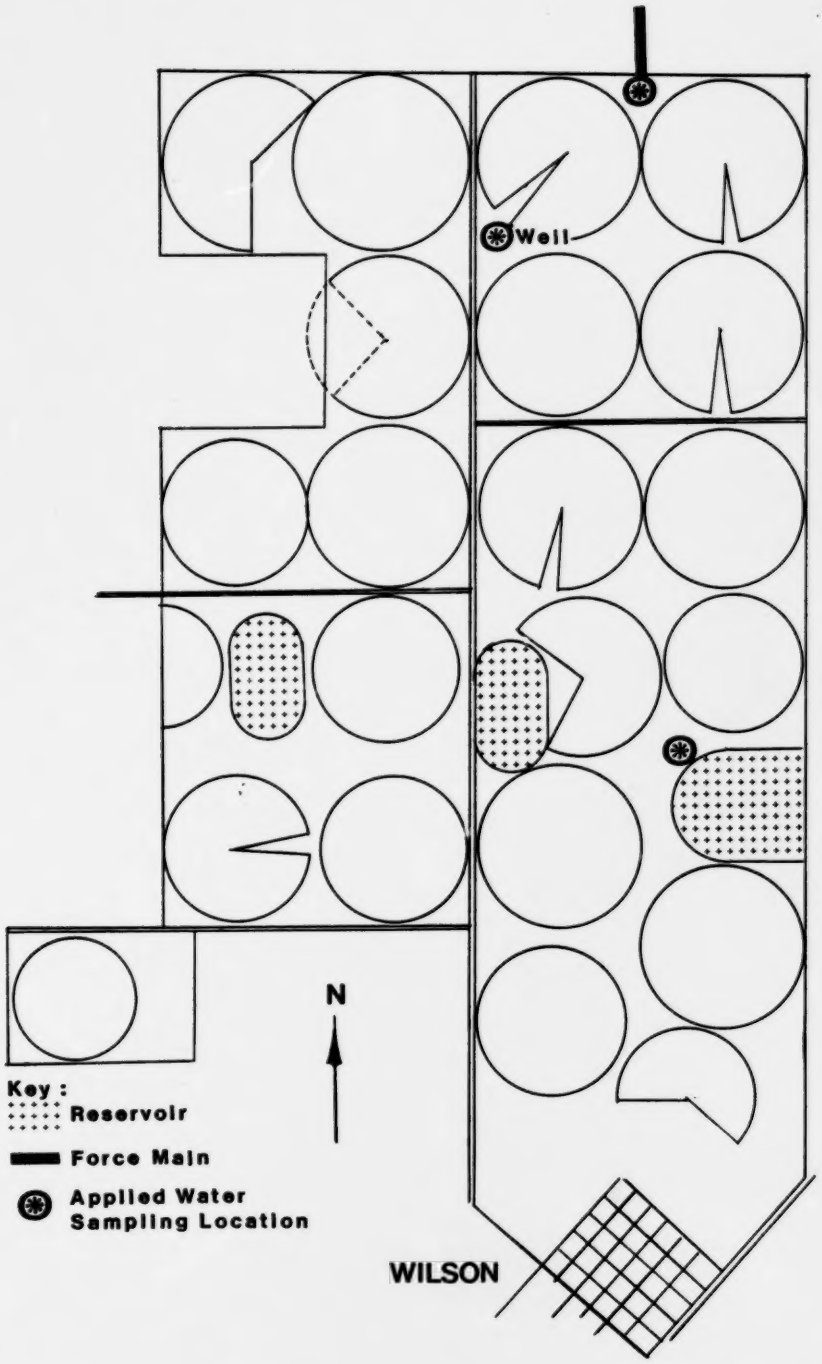


Figure 3. Sampling Locations for Water Applied to Research Plots

ectly from the distribution pipeline as the effluent was pumped to the Hancock farm from the City of Lubbock; 2) from the reservoir wastewater discharge; 3) from a ground-water well used to provide fresh water for Treatments 10, 11, and 12 in Trial 16000. Soil and crop samples were collected from each trial. The soil and crop sampling locations within replications (reps) of a treatment were randomly selected. Soil and crop samples were composited across reps to obtain a representative sample of each treatment.

Water

Irrigation water applied to the crops was monitored throughout the project period during the growing season. Well water and effluent water were used for irrigation of the research plots, depending upon treatment. In 1982 approximately 85 percent of the effluent applied to test plots was derived directly from the pipeline, prior to the reservoirs, and 15 percent of the effluent came from the reservoirs. The following year 80 percent of the effluent was obtained from the storage reservoirs and the remaining 20 percent from the pipeline prior to reservoir storage. A well located adjacent to research plots, was used for the fresh water source. The fresh water source was sampled in April, August, and December of each year. The effluent water from the City of Lubbock was sampled monthly during the irrigation seasons as the waste stream arrived at the Hancock farm and from the reservoirs. The exact position of the effluent monitoring location was usually the effluent box at the northern end of the farm where the effluent force main from the City sewage treatment plant entered the farm.

Sampling procedure, preservation and analyses--

The sampling procedure, sample custody, sample preservation, analyses and analytical procedures were the same as those employed in Volume I of the Lubbock Land Treatment System Research and Demonstration Project (George et al 1985). In general, for the fresh water sample, water samples were obtained from a faucet at the surface of the well after 15 minutes of pumping. The water samples were taken directly into a sterile bottle for

bacteriological analysis, glass bottle for priority organic analysis, and polyethylene bottles for nutrients, physicals, metals and other inorganic analyses. Table 5 lists the parameters analyzed for in the applied water samples. The samples were placed in an ice chest for transport to the lab. The water samples were analyzed or preserved the same day as taken, according to the Environmental Protection Agency (EPA) approved procedures outlined in the Lubbock Land Treatment System Research and Demonstration Project: Volume I (George et al 1985)

Soils

Each year prior to pre-irrigation (April) and after harvest (latter part of October through December), soil samples were obtained representing each treatment and crop within a trial. Depending upon the particular number of treatments and reps per trial, one to three soil cores were taken per plot, composited within a plot, and composited across reps. Table A.1 lists by Trial the soil compositing protocol employed in 1982 and 1983.

Sampling Procedure, Preservation, and Analyses--

The sampling procedures used were the same as those described in detail in the monitoring section of the Lubbock Land Treatment System Research and Demonstration Project: Volume I (George et al 1985). Soil cores were obtained with a Gidding's soil coring and sampling machine using a 10.2 cm (4 in) diameter, 1.2 m (4 ft) long coring tube with a quick relief bit. In the field, the core was divided into 30 cm (1 ft) sections on a clean board brushed off between samples. Each 30 cm (1 ft) section was thoroughly mixed and portioned into sample containers. If several cores were composited to make a single sample, then a portion of each thoroughly mixed section was put into the same container corresponding to that depth. In the field, the sample was put into a 10.3 cm x 25.4 cm (8 in x 10 in) or 27.9 cm x 40.6 cm (11 in x 16 in) sterile polyethylene bag and sealed with a wire twist. The samples were immediately placed in ice chests and transferred to the Lubbock Christian College Institute of Water Research (LCCIWR) Laboratory by 4:00 p.m. that day. Once the samples were

TABLE 5. APPLIED WATER ANALYSIS

Alkalinity (Alk) mg/l $CaCO_3$	Aluminum (Al) mg/l*
Total Organic Carbon (TOC)	Arsenic (As) mg/l*
Conductivity µmhos/cm	Barium (Ba) mg/l*
Total Dissolved Solids (TDS) mg/l	Boron (B) mg/l*
pH	Calcium (Ca) mg/l*
Chloride (Cl) mg/Cl^-/l	Cadmium (Cd) mg/l*
Total Kjeldahl Nitrogen (TKN) mg N/l	Cobalt (Co) mg/l*
Nitrite plus Nitrate (NO_2 + NO_3 mg/N/l	Chromium (Cr) mg/l*
Ammonia (NH_3) mg N/l	Copper (Cu) mg/l*
Total Phosphorus (TP) mg P/l	Iron (Fe) mg/l*
Ortho Phosphate Phosphorus (PO_4) mg P/l	Lead (Pb) mg/l*
Organic phosphorus (Org. P) mg P/l	Magnesium (Mg) mg/l*
Chemical Oxygen Demand (COD) mg/l	Manganese (Mn) mg/l*
Sulfate (SO_4) mg SO_4/l	Mercury (Hg) mg/l*
Total Coliform (TC)/100 ml	Molybdenum (Mo) mg/l*
Fecal Coliform (FC)/100 m	Nickel (Ni) mg/l*
Fecal Streptococcus (FS)/100 ml	Potassium (K) mg/l*
Salmonella/300 ml	Selenium)Se) mg/l*
	Silver (Ag) mg/l*
	Sodium (Na) mg/l*
	Thallium (Tl) mg/l*
	Zinc (Zn) mg/l*

*Total and Dissolved

received at the laboratory, the soil in the polyethylene bag was divided as follows:

1. A portion was separated into a sterile container for microbiological analysis;
2. A second portion was weighed directly into ammonia extracting solution; and
3. A third portion was poured into drying pans to be air dried and and ground.

Table 6 lists the parameters analyzed for in the soil samples. The methods of sample preservation and analysis were the same as those cited in Lubbock Land Treatment System Research and Demonstration Project: Volume I (George et al 1985).

Crops

Once the crop was ready to be harvested, samples of crops for each treatment were taken for yield tests and analysis. The whole plant was divided into its plant parts (i.e., stalk, leaf, seed, etc.) prior to processing for analyses. Because of the analytical load, compositing was usually performed to obtain one sample per plant part per crop per treatment for laboratory analysis. Discrete crop samples for yield tests (weight of dry fruit per area) were obtained from each test plot within a Trial. Table A.2 lists the crop sampling protocol by Trial for 1982 and 1983.

Sampling Procedure, Preservation and Analyses--

At the time of sampling the entire plant was cut at the surface of the soil and placed in a sterile plastic bag. A crop sample within a plot consisted of all the plants in a one meter length of row of cotton, milo, and soybeans and a two meter square area for solid planted crops (bermuda and alfalfa). The sample area within a plot was randomly selected. The crop samples were taken to the LCCIWR Laboratory the same day as removed from the field. At the laboratory, a major portion of each sample was removed aseptically, divided into plant parts, and placed in aluminum pans or paper sacks for drying. The crop sample remaining in the plastic bags was placed in a walk-in cold box until the plant parts were composited (if

TABLE 6. SOIL ANALYSIS

Wet Chemistry	Microbiological	Metals* (mg/kg)
Alk mg $CaCO_3$/g	Total Coliform (TC)/g	Al
Conductivity µmhos/cm	Fecal Coliform (FC)/g	As
TDS mg/g	Fecal Strep (FS)/g	B
pH	Antinomycetes/g	Ca
Cl mg/g		Cd
TKN mg N/g		Fe
NO_2 + NO_3 mg N/g		Mg
NH_3 mg N/g		Mn
TP mg P/g		K
PO_4 mg P/g		Na
SO_4 mg SO_4/g		Zn
Organic Matter		
Buffer Capacity		
Organic N mg N/g		
Organic P mg/g		
Organic Carbon mg C/g		
Particle Density g/cm^3		
Texture		
Bulk Density		
Percent Moisture		

*Total and Available

required) and microbiologically analyzed. After the samples were dried, they were weighed and the yields calculated. As required portions of each sample were composited prior to grinding and further analysis. Table 7 lists the parameters analyzed in the plant tissue samples. Detailed sampling procedures and methods of sample preservation, preparation and analysis are given in the methods section of the Lubbock Land Treatment System Research and Demonstration Project: Volume I (George et al 1985).

Quality Assurance

Quality Control--

Duplicate analysis was conducted on every tenth water, soil, or crop sample. In addition, every tenth sample analyzed for organic or inorganic constituents was spiked with the particular compound or element being tested to determine the accuracy of the laboratory procedures. Tables A.6, A.7, and A.8 present a summary of the precision and accuracy data for the laboratory procedures applied to water, soil, and crop samples during the project. LCCIWR, also, received "Quality Control Reference Samples" from the Environmental Monitoring and Support Laboratory (EMSL), the U.S. Environmental Protection Agency, Cincinnati, Ohio every six months. The results of these analyses are presented in Table A.9. Inhouse quality control reference samples were tested to determine the accuracy of specific laboratory procedures employed and addressed the discrepancies between values obtained for a particular analysis.

Furthermore, quality assurance reproducibility data were obtained for indicator bacteria in Lubbock's wastewater by splitting wastewater samples with the University of Texas at San Antonio, Texas laboratory, and the University of Texas at Austin, Texas laboratory. Tables A.10, A.11, and A.12 provide the results of indicator bacteria analysis of wastewater samples divided between the various laboratories. In general, total coliform, fecal coliform, and fecal streptococci values were within the expected variability of a dilution-based bacterial assay. Duplicate bacterial assays by LCCIWR produced values which were closer to the mean of triplicate platings by University of Texas laboratories.

TABLE 7. CROP ANALYSIS PROTOCOL

COTTON

Lint, Seed, Burs, Stems:
TC, FC, FS
TKN, TP, S
K, Ca, Mg, Na, Zn, Mn, Fe, B, Al, Cd, As

Seed:
Protein, Cl, Oil

GRAIN SORGHUM (MILO)

Grain, Stalk, Leaf:
TC, FC, FS
TKN, TP, S, Cl
K, Ca, Mg, Na, Zn, Mn, Fe, B, Al, Cd, As

Stalks, Leaf:
HCN, Fiber

Grain:
Protein, Starch, Oil

ALFALFA, BERMUDA

Whole Plant:
TC, FC, FS
TKN, TP, S, Protein, Cl
K, Ca, Mg, Na, Zn, Mn, Fe, B, Al, Cd, As
Fiber

SOYBEANS, SUNFLOWERS

Leaf, Stem, Seed:
TC, FC, FS
TKN, TP, Cl
K, Ca, Mg, Na, Zn, Mn, Fe, B, Al, Cd, As

Seed:
Protein, S, Oil

Sample Custody--

At the time of sampling, the sample container was marked with the field code of the sample. The field code, exemplified in Figure A.1, contained the sample date, site location, identifying number, sample type, sampling method, depth of samples, type of crop and plant part. As the samples were received at LCCIWR, the samples were logged onto sample receiving forms and the samples were given an LCCIWR lab number. Sample analysis data were entered into the computer according to the LCCIWR lab number and field code.

Data Reduction, Validation, and Reporting--

Arithmetic averages and confidence intervals of each parameter were computed. Data which was not within the confidence interval was identified. Data worksheets for outliers were checked for mathematical errors, dilution errors, or analytical errors. Spikes, duplicates and inhouse unknowns were evaluated to determine analytical performance during the assay period. Once evaluation of the supportive information indicated a high degree of analytical precision and accuracy, and no data reduction or analytical errors, the data was considered valid. In addition, an ion balance was conducted on each water sample to insure electrical neutrality. Data yielding anion to cation ratios less than 0.70 and greater than 1.2 were delineated and verified as previously stated.

Figure A.2 presents a data flow diagram. Key individuals who handled data are also delineated in Figure A.2.

Performance System Audits--

Performance and system audits were maintained throughout each year of the project. First, review of laboratory performance was formally made each quarter as internal quality control data was compiled. Second, quality assurance unknowns from EPA EMSL-CI were analyzed twice each year. Third, laboratory and field quality control, operation, problem areas, and schedule of events were discussed at weekly research and laboratory team meetings.

Specific Routine Procedures Used to Assess Data Precision and Accuracy--

Precision and accuracy of the measurement systems was determined by analyzing duplicate samples and spiked samples for every tenth sample tested. Daily control of analytical performance was achieved through the use of Shewhart Quality Control Charts. Precision control charts were prepared from data resulting from duplicate sample analyses. Accuracy control charts were constructed from duplicate spiked samples. The recorded difference between duplicate samples was never less than half the minimum detection limit.

Quality Assurance Reports to Management--

Quality assurance reports were written quarterly as part of the project quarterly reports. Each section head (i.e., wet chemistry, organics, metals, soils, microbiology, and assistant lab supervisor) reported their quarterly quality control data in tables for each parameter analyzed. The accuracy, precision, inhouse unknowns and EPA unknowns data was analyzed and reported in a "Quality Control" section of quarterly and annual reports. All quality control raw data was presented quarterly in the quarterly report appendices. In addition, these quality assurance sections included (1) periodic assessment of measurement data accuracy, precision and completeness, (2) results of performance audits, (3) results of system audits, and (4) significant QA problems and recommended solutions.

The quality control section of the quarterly reports were prepared by Dr. Blair Leftwich, the LCCIWR QA Officer, from the information supplied to him by his staff. Quality assurance to management regarding field work was supplied by the projects managers of each study. These reports were evaluated and written into the quarterly and annual reports by the LCCIWR lab director, Dr. Dennis George. Quarterly and annual reports containing quality assurance data were distributed to EPA, Texas Dept. of Water Resources, project managers, LCCIWR board, and the City of Lubbock.

Corrective Action--

Corrective action applied to both field and laboratory work and represented the need for improvement. Corrective action was initiated by the

section head responsible for the work, assistant lab supervisor, lab supervisor, assistant institute director, or institute director and occurred in the order stated.

The need for improvement of field work was denoted by site visits and lack of consistent, recorded field data. The corrective action concerning field work was to meet with the personnel doing the field work, innumerate the problems and determine a solution to be applied.

For the laboratory, the need for corrective action was based on inadequate performance on internal quality control (duplicates, knowns and spikes), standards, inhouse unknowns, EPA reference samples and sample analysis. If a problem was noted and corrective action was needed, the technician first checked his calculations, then remade standards, then remade reagents, and finally checked equipment. Once the problem was corrected and proper standard curves were obtained, the spikes, duplicates, knowns and unknowns were repeated.

SECTION 5

RESULTS AND DISCUSSION

WASTEWATER EFFLUENT

Agricultural research activities were performed on the Hancock farm. Secondary treated wastewater from Lubbock's Southeast Water Reclamation Plant (SeWRP) was pumped a distance of approximately 25 km to the northern boundary of the Hancock farm. At the Hancock farm, the effluent was routed through three 0.38 m plastic irrigation pipelines to three separate reservoirs (Figure 4). Irrigation pump stations were provided at each reservoir. The irrigation system was designed to irrigate 1153 ha.

During 1980 and 1981, SeWRP was producing an effluent (Table B.1) which had a composition equivalent to a typical medium untreated domestic wastewater (Tchobanoglous 1979). The poor quality effluent was primarily attributable to malfunctioning of the anaerobic digestion process. Effective liquid-solid phase separation was not achieved in the second stage digester. Consequently, the suspension recycled from the anaerobic process to the head works of the trickling filter plant contained high levels of ammonia, suspended solids and carbonaceous material. From June 1980 to February 1982, the average effluent total organic carbon (TOC) produced was 117.7 mg/l. Total Kjeldahl nitrogen (TKN) concentration averaged 38.59 mg-N/l of which 67 percent was ammonia-nitrogen (25.95 mg-N/l) and 33 percent was organic nitrogen. Due to high organic mass loadings and subsequent heterotrophic organism activity, the trickling filter system was not nitrifying ammonia to nitrate. Approximately 57 percent of the total phosphorus (14.43 mg/l) present in the effluent was orthophosphate phosphorus (PO_4). Additional anaerobic digesters were placed on operation in the spring of 1982. Furthermore, the primary clarifiers and rotary distributors of the trickling filter plants were rehabilitated. The data (Table B.1) indicate a much higher quality waste stream pumped to the Hancock farm in 1982 through 1983. TOC levels at the terminus of the force main were 46 percent less than the average concentrations measured in SeWRP's effluent samples obtained the previous sampling periods.

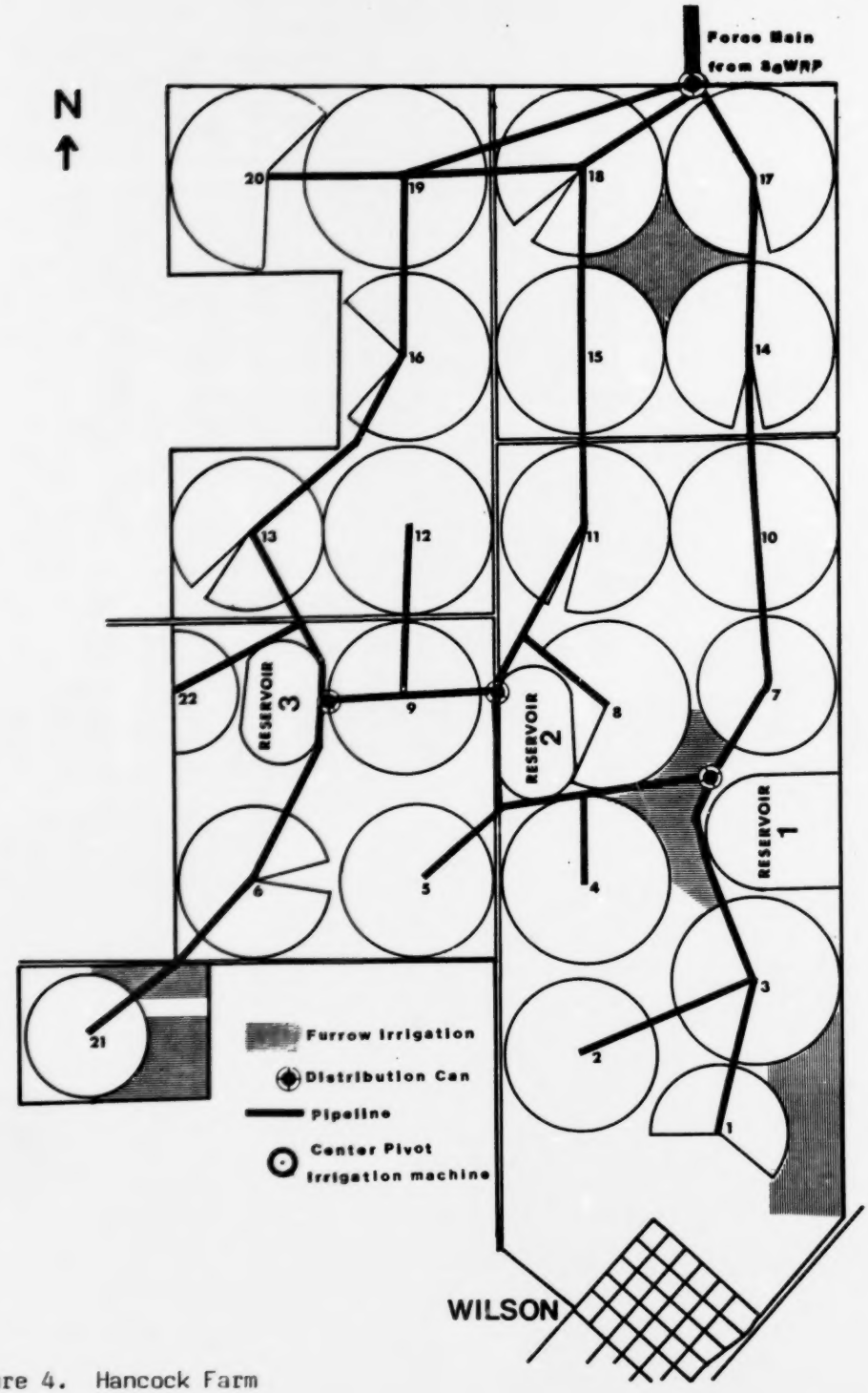


Figure 4. Hancock Farm

No statistically significant differences (α = 0.05) were observed in TKN levels measured in the waste stream from SeWRP (38.59 mg-N/l) and at the terminus of the force main (41.70 mg-N/l). As SeWRP's effluent reached the farm, 62 percent of the TKN was ammonia-nitrogen (25.80 mg-N/l). Ammonia-nitrogen was not significantly different (α = 0.05) from the concentration measured in the plant's effluent. Therefore, the data indicated no nitrogen transformation through the force main. Total phosphorus (TP) and organic phosphorus (Org P) levels (11.82 mg/l and 1.6 mg/l) contained in water samples obtained from the terminus of the force main did decrease significantly from baseline (1980 and 1981) effluent concentrations. Orthophosphate phosphorus (PO_4) levels measured at both locations were statistically equivalent. Consequently, the decrease in TP appears to be a result of a decrease in organic phosphorus mass loading from the plant. The improved anaerobic digestion capacity and solids-liquid separation of digested sludge was probably the major contributing factor to the decrease in organic phosphorus levels in the effluent.

As anticipated, the bulk (71 percent) of the nitrogen contained in the water entering the Hancock farm (41.77 mg-N/l) was lost within the reservoirs. Average reservoir effluent TKN concentration was 11.74 mg-N/l. The median NO_2 + NO_3 level in the reservoir discharge stream was 0.27 mg-N/l. Nitrification of ammonia to nitrite and nitrate does not normally occur in stabilization ponds (Ferrara and Harleman 1978; Pano and Middlebrooks 1982, Ferrara and Avci 1982). Insufficient nitrifiers exist in the upper aerobic zone of the pond. Low nitrifier population can result from inhibition by algae, lack of aerobic surface area to facilitate attachment and growth, or adsorption of organisms to particulates which settle into the anaerobic zone (Ferrara and Harleman 1978; Stone et al 1975). Sporatic checks of dissolved oxygen (DO) concentration within the water column of the largest reservoir indicated one mg/l or less of DO in the upper 61 cm. No dissolved oxygen was measured below 61 cm. Stoichiometrically the nitrification process requires 4.57 mg O_2 for each mg of ammonia oxidized (Christensen and Harremoes 1978). Due to the low DO concentration limiting biochemical kinetic reactions, nitrification was probably not a major contributor to the decrease in TKN. Ammonia nitrogen in water exist as

ammonium ion (NH_4^+) and dissolved ammonia gas (NH_{3_g}). The concentration of the volatile NH_{3_g} present in water is a function of pH, temperature, and concentration of total ammonia. With water temperatures varying from 10 to 21°C, a maximum of about 7.4 percent NH_{3_g} was present in the reservoir water column at an average pH of 8.3. Loss of NH_{3_g} to the atmosphere results in continued dissociation of ammonium nitrogen to dissolved ammonia gas. With hydraulic residence time generally greater than 100 days, and substantial wind mixing of the reservoirs, significant quantities of ammonia nitrogen can be lost due to volatilization. The most probable mechanism for loss of nitrogen within the water column in the reservoirs was ammonia volatilization.

Algae growing in alkaline, hard water prefer bicarbonate rather than carbon dioxide as a carbon source (Wetzel 1975). The enzyme-catalyzed uptake of bicarbonate produces a strong base:

$$HCO_3 \rightleftharpoons CO_2 + OH^- \qquad (1)$$

Ruttner (1963) noted that algae which utilized bicarbonate exerted a significant effect on water pH. This effect was also observed in the Hancock reservoirs. The average pH of 8.30 in the reservoir was significantly ($\alpha = 0.05$) greater than the effluent pH of 7.76 produced by SeWRP.

Data presented in Appendix B indicate approximately 85 percent of the total phosphorus contained in the effluent (11.82 mg/l) pumped to the Hancock farm was orthophosphate (8.43 mg/l). Assimilation of orthophosphate phosphorus by biomass for cell synthesis and adsorption of orthophosphate to solids followed by sedimentation decreased PO_4 through the Hancock reservoirs from an average level of 8.43 mg/l to 4.85 mg/l. Total phosphorus concentration was reduced by 47 percent from 11.82 mg/l to 6.31 mg/l. Orthophosphate removal in the reservoir account for about 65 percent of the decrease in TP.

The sewage treated by SeWRP was primarily derived from domestic sources with less than 30 percent contributed from industrial sources. Trace metal levels contained in SeWRP effluent (Table B.1) reflected this low industrial wastewater flow and presented no potential phytotoxicity problems (Table B.2). No significant differences ($\alpha = 0.05$) in trace

metal and mineral levels were determined between any irrigation water sources from February 1982 to October 1983.

The data indicate that minerals, particularly sodium (Na), may create salinity and sodic problems within the upper soil profile. The effluent produced by SeWRP was slightly saline (dissolved solids from 1000 to 3000 mg/l). The low hydraulic loading to the Hancock farm (20 to 60 cm) could create accumulation of salts within the upper soil profile. Without proper salt management, salts could pose future phytotoxicity problems to farmers. The sodium absorption ratio (SAR) of the effluent stream from SeWRP averaged 9.84. Evaporation and transpiration remove water from the soil, thereby concentrating calcium and magnesium carbonates in the soil solution and eventually resulting in formation of calcium and magnesium carbonate precipitates. Reduction of these cations from the soil solution increases the SAR. Accounting for calcium and magnesium carbonate precipitation, the adjusted SAR for the effluent was 21.6. Irrigation water with an adjusted SAR of about ten may create severe water penetration problems and development of alkali soils (Stromberg and Tisdale 1979; EPA 1981; Loehr et al 1979). Proper management of salts contained in the irrigation water was viewed as the most important task which would govern the long term success of the land application system.

As indicated previously, all crops were planted by mid-May. Rainfall and associated hail during the month of May and June 1982 (Figure 5) destroyed over 8.09×10^5 ha (2×10^6 ac) of the cotton crop in the South Plains.

SOILS

Soil texture within the upper 30 cm (1 ft) of the soil profile were generally sandy clay loam. Clay to clay loams dominated the soils from a depth of 30 cm to 122 cm (4 ft) within the profile. The majority of soils from 122 cm to 183 cm (6 ft) were clays. An indurate layer of calcium carbonate (caliche) existed within the soil profile at a depth of 61 cm to 183 cm below the surface throughout the farm. Soils at the Hancock farm were alkaline and calcareous with pH values of seven to eight within the upper 183 cm. Cation exchange capacities (CEC) were greater than 20

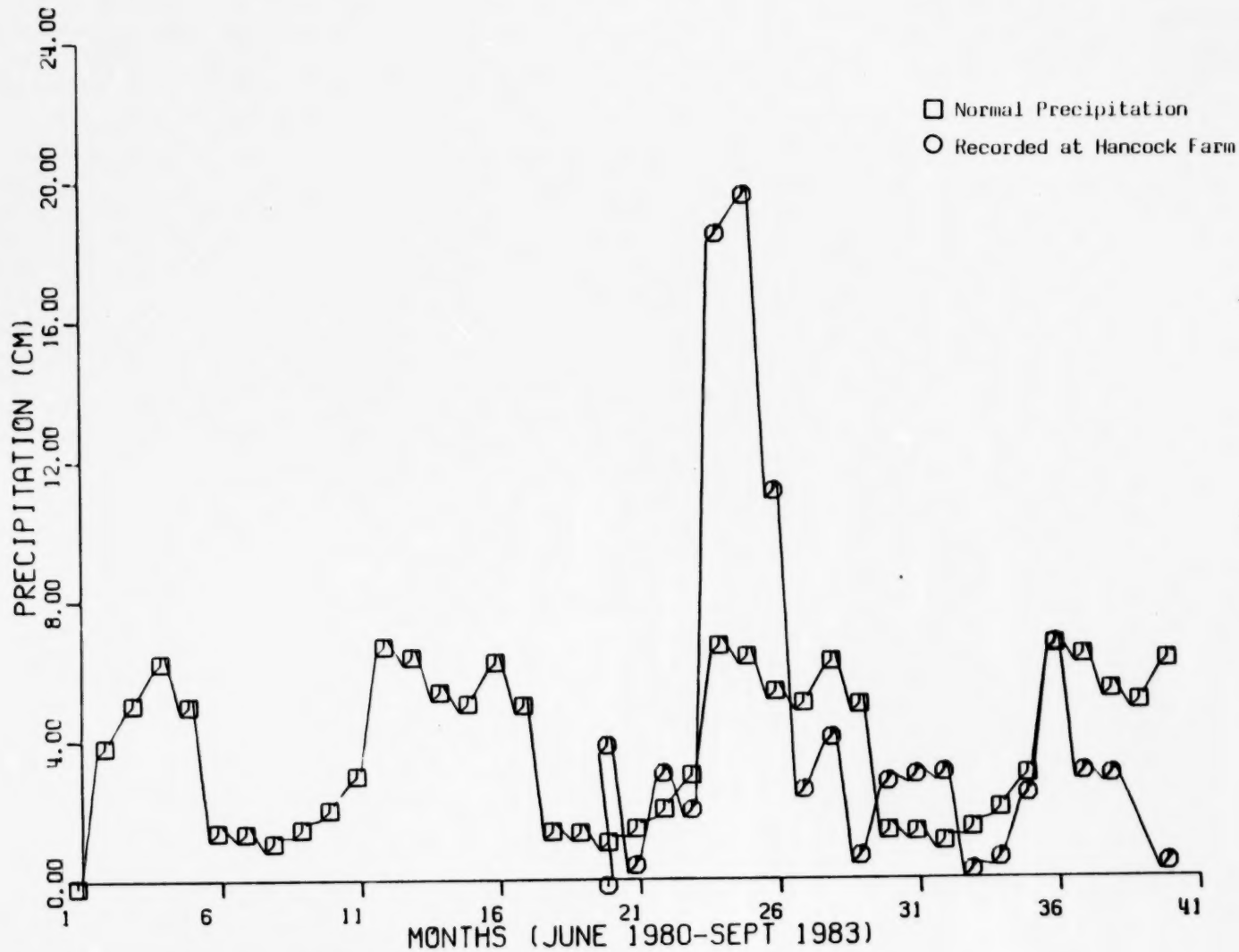


Figure 5. Monthly Precipitation During Project Period

meq/100 g (average 23.6 mg/100 g ± 3.3) which were characteristic of the clay/clay loam soils.

HYDRAULIC LOADING STUDY (Trials 14000, 15000, and 16000)

Grain Sorghum (Milo)

Crop Quality--

Crop yield data (Table 8) indicated milo yield increased as wastewater application increased up to approximately 3 m/yr. Milo yields obtained from dry land plots in 1982 were greater than dry land yields produced in 1983 primarily due to higher soil moisture conditions resulting from the precipitation in May and June (38.4 cm).

TABLE 8. GRAIN SORGHUM PRODUCTION FOR EACH ANNUAL HYDRAULIC LOADING RATE

Year	Treatment	Hydraulic Loading (m/yr)	Yield Average (kg/ha)	Yield ±Standard Deviation	Coefficient of Variability(CV)
1982	5	0.00	4930	832	17%
	1	0.61	5730	723	13%
	2	0.61	6400	170	3%
	3	0.91	6460	170	3%
	4	1.06	6840	1220	18%
1983	5	0.00	0	0	
	1	1.37	4450	755	17%
	2	1.83	5020	1100	22%
	3	2.13	5070	1290	25%
	4	2.82	5160	1250	24%

The concentration of specific chemical constituents in the crop tissue is presented in Table C.1. Nitrogen in the stalk and leaf tissue exhibited a drastic decline in 1983 (1700 ppm to 3640 ppm) compared to

1982 crop tissue samples (13,700 ppm to 17,200 ppm). Furthermore, the seed harvested in 1983 contained less protein concentration (6.25 x percent TKN) than levels measured in the 1982 crop.

The average TKN in the seed harvested in 1982 was 16,600 $\pm$ 904 mg/kg. Crop growth did not appear to be inhibited by nitrogen limitations. Equal concentrations of nitrogen were presented in the stalk tissue as in the grain. In 1983, reduced levels of available nitrogen in the soil solution limited crop growth and protein production. Decreased levels of nitrogen in the crop tissue were translocated to the seed for protein synthesis; consequently, lower levels of TKN were measured in the stalk tissue.

The nitrogen deficiency experienced in 1983 is also shown in the K/N ratio for the various parts of the crop (Table C.7). Potassium (K) is a vital element in plant growth and is removed from the soil more than any other element except nitrogen. Wastewater K/N ratio of 0.9 or greater will satisfy the K nutrient requirement of forage crops (Palazzo and Jenkins 1979). The average K/N ratio in the wastewater ranged from 0.71 (pipeline) to 2.43 (reservoir). Therefore, the majority of the K applied, if available to the crop, should be assimilated into the crop. In calcareous soils, however, calcium competes with K for entrance into the plant (Potash Institute of America, 1973). Consequently, calcareous soils may require higher available K levels. Potassium levels in the various parts of the plant exhibited a slight increase from 1982 to 1983 crops. Potassium did not appear to retard nitrogen transport into or through the crops.

Total phosphorus (TP) concentrations in the tissue were greater in 1983 crops than in 1982 crops (Table C.1). More phosphorus was measured in the seed tissue than stalk. Phosphorus within the plant is involved in photosynthesis; hastening maturity; stimulating blooming and seed formation; and stimulation of early root growth. Increased TP mass loadings through irrigation were the probable source of phosphorus to the plant. Phosphorus to zinc ratios in the stalk tissue ranged from 12 to 89 in 1982 and 64 to 130 in 1983. The grain sorghum harvested in 1983 from Treatment 4 (2.82 m/yr) was the only crop which maintained a P:Zn ratio equivalent to or exceeding recommended values of 125 (Inter-American Labs 1978, A & L

Labs Soil and Tissue Analysis Handbook). Therefore, phosphorus may have limited seed production in 1982 and 1983.

Chlorides, calcium, iron, manganese, potassium, and sodium exhibited higher concentration in the stalk tissue than in the grain (Table C.1). Chloride concentrations contained in stalk assayed in 1983 were higher than levels measured in the 1982 crop. Seed chloride concentrations, however, showed the opposite trend. With more frequent saturated conditions within the upper soil profile, ferric and manganese IV oxides were probably reduced to more soluble ferrous and manganese II ion and consequently were more available to the crop. Higher concentrations of potassium (19,000 ppm) and sodium (231 ppm) were present in the stalk tissue produced in the dryland plots due to a reduction in water availability. As soil moisture decreases, the concentrations of salt in soil solution increase and more salts are transported into the plant. With irrigation, a higher percent available water may be present in the soil profile and salts in the soil solution are diluted.

Cadmium and phosphorus were present at higher concentrations in the seed than in the stalk. Cadmium within both the stalk and seed tissue was less than detection limits (<0.05 ppm) in the 1983 milo harvest.

Soils--

Nitrogen--Nitrogen applied to soils is removed from the wastewater stream by adsorption, crop utilization, and gaseous nitrogen losses by ammonia volatilization and/or dinitrogen (N_2) and nitrous oxide evolution through the denitrification process. Nitrogen loss due to ammonia volatilization is increased in soils with high calcium carbonate concentrations, pH above 7, low cation exchange capacity, low buffering capacity, warm temperatures, decreased soil moisture and high ammonium concentrations at the soil surface (Fenn 1975; Gasser 1969; Fenn and Kessel 1974). Due to the CEC value, volatile ammonia may have been adsorbed onto clay material; thereby preventing the escape of ammonia from the soil matrix. The CEC value in conjunction with the soil pH level indicated volatilization probably did not contribute significantly to nitrogen losses.

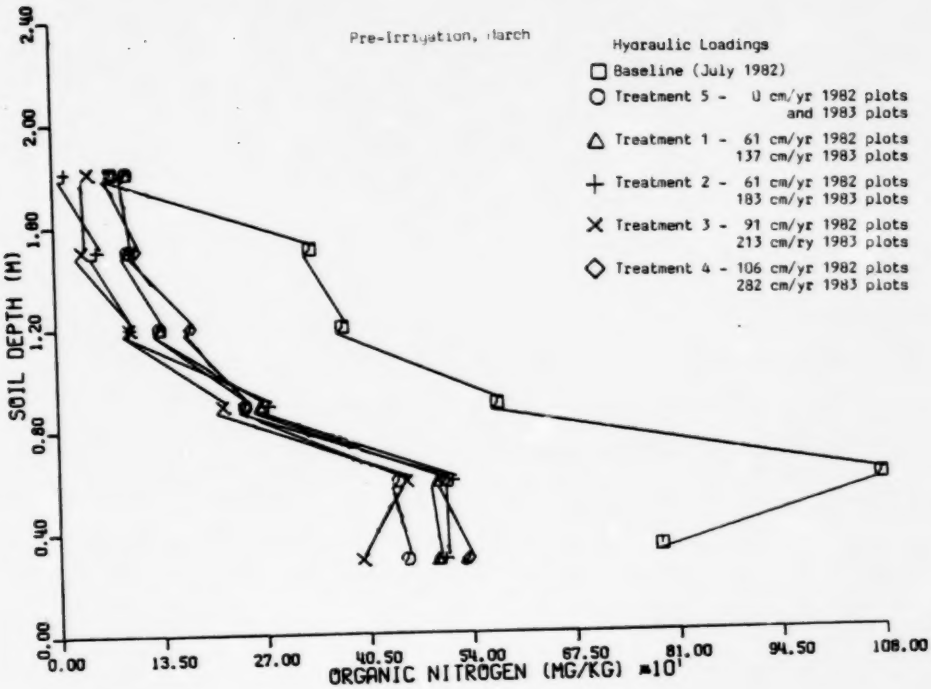
The bulk of the nitrogen in the soil profile was organic nitrogen.

Organic nitrogen comprised greater than 97 percent of the soil TKN (Table 9). Baseline soil cores extracted prior to irrigation showed an accumulation of organic nitrogen within the 30 cm to 61 cm depth and a larger decrease in organic nitrogen from 61 cm to 183 cm (Figure 6). Carbon to nitrogen (C/N) ratios of the organic matter within the upper 152 cm ranged from 5.4 to 11.0 in 1982. In addition, the average C/N ratios of the effluent pumped to the farm and from the reservoirs were 4.0 and 5.9, respectively. Generally, at a C/N ratio of approximately 22 and a N percentage of two, mineralization of organic nitrogen equals the immobilization of organic nitrogen (Campbell 1978; Loehr 1979). Smaller C/N ratios are associated with net mineralization and ratios higher than 22 indicate net immobilization. Therefore, net mineralization of organic nitrogen predominated within the soil profile.

TABLE 9. NITROGEN IN THE TOP 183 CM OF SOIL PROFILE BENEATH TRIAL 15000 GRAIN SORGHUM PLOTS

Treatment	Annual Hydraulic Loading (m/yr)	TKN Mass (kg/ha)		Organic N Mass (kg/ha)		Organic N % of TKN	
		March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983
1	1.37	6870	8580	6870	8570	100%	100%
2	1.83	6870	7340	6350	7330	92%	100%
3	2.13	5890	7680	5410	7680	92%	100%
4	2.82	7130	7380	7120	7380	100%	100%
5	0	6400	7640	6390	7690	100%	100%

It appears by the difference between the baseline (late June-early July 1982) and fall 1982 organic N profile that net mineralization of nitrogen did occur in 1982. Organic nitrogen decreased within the upper 152 cm of soil in all plots (Figure 6). Baseline soil cores, however, were collected from within the area of each Trial and composited; whereas, durng the remainder of the project, soil cores obtained from each treatment in a Trial were collected from within the area of each replicate plot and composited. Therefore, decreases in organic nitrogen concentrations in the soil profile may have been an artifact of the differences in sampling procedure employed in 1982. Soil organic N data collected in the



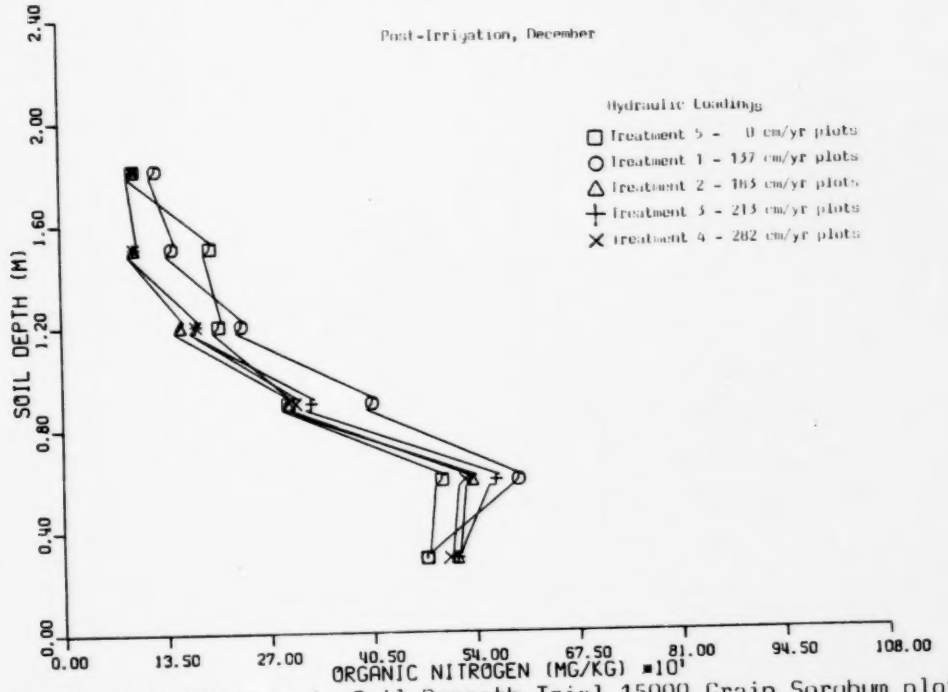


Figure 6. Organic Nitrogen in Soil Beneath Trial 15000 Grain Sorghum plots, 1983

fall 1983 did not vary greatly from concentrations measured in the fall 1982. Major input of organic nitrogen at the end of the 1982 growing season was the incorporation of milo leaf and stalk material into the soil matrix. The major nitrogen form applied to the land through irrigation was ammonia. Fall 1982 soil samples indicated nitrite plus nitrate (NO_2 + NO_3-N) nitrogen levels in the upper 61 cm of soil were greater than baseline or dryland plots (Figure 7). A lens of NO_3-N was observed in the dryland plot commencing at 122 cm and reaching a maximum 16.4 mg-N/kg at 152 cm depth. The nitrate lens apparently diminished during the 1983 growing season (Figure 7). The NO_2 + NO_3-N concentration was quite uniform throughout the soil profile in all treatments in the fall 1983.

A nitrogen mass balance for the five treatments in 1983 was conducted to help delineate major mechanisms governing nitrogen movement within the soil profile. Nitrogen inputs to the soil were primarily a result of effluent irrigation. An additional source of nitrogen is through precipitation. Inorganic and organic nitrogen within the soil profile may be sources and/or sinks of nitrogen. Nitrogen is lost by volatilization, crop uptake and harvest, deep percolation, and denitrification. Nitrogen losses due to volatilization were assumed negligible. With the hydraulic loading ranging from 137cm/yr to 282 cm/yr denitrification of NO_3-N probably occurred within 36 hours after each irrigation event (Ryden et al 1981). The following mathematical relationship presented by Mehran et al (1981) was used to compute a nitrogen mass balance:

$$N_{ior}| = N_{iort-1} + K(e_{ir} \cdot Q_{ir} + (1-a)C_pQ_p) + (1-g)N_{Aior} + (1-d)(1-e^{-k_{m1}t})N_{Aor} + (1-e^{-k_{m2}t})N_{fn} + (1-e^{-k_{m3}t})N_{or}|t-1 \quad (2)$$

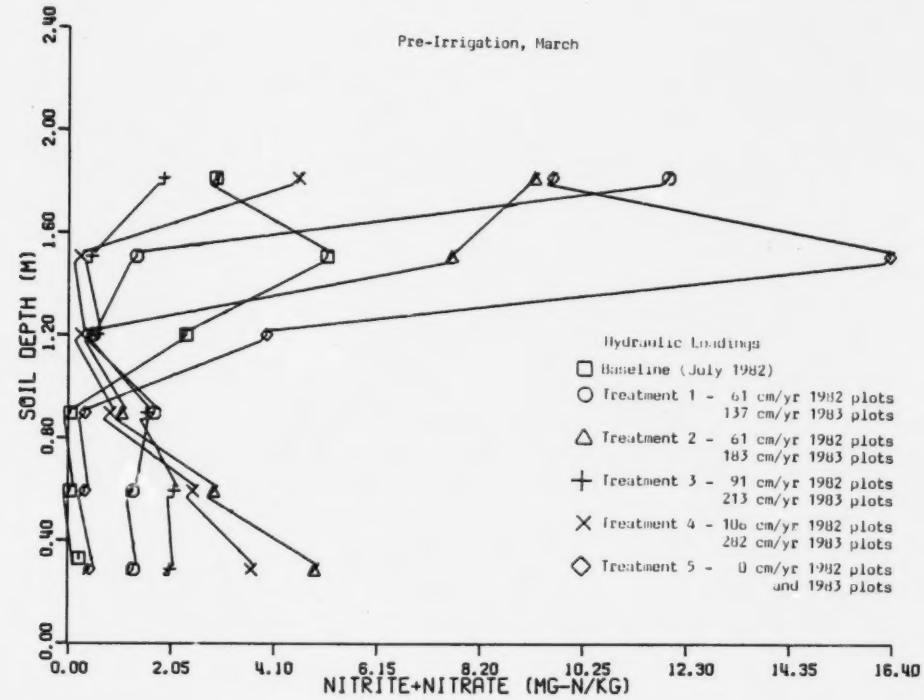
Where N_{ior} = Inorganic nitrogen in soil profile (kg/ha-yr),

N_{Aior} = Applied inorganic nitrogen fertilizer (kg/ha-yr),

N_{Aor} = Applied organic nitrogen fertilizer (kg/ha-yr),

N_{fn} = Fixed nitrogen (kg/ha-yr),

N_{or} = Organic nitrogen in soil profile (kg/ha-yr),



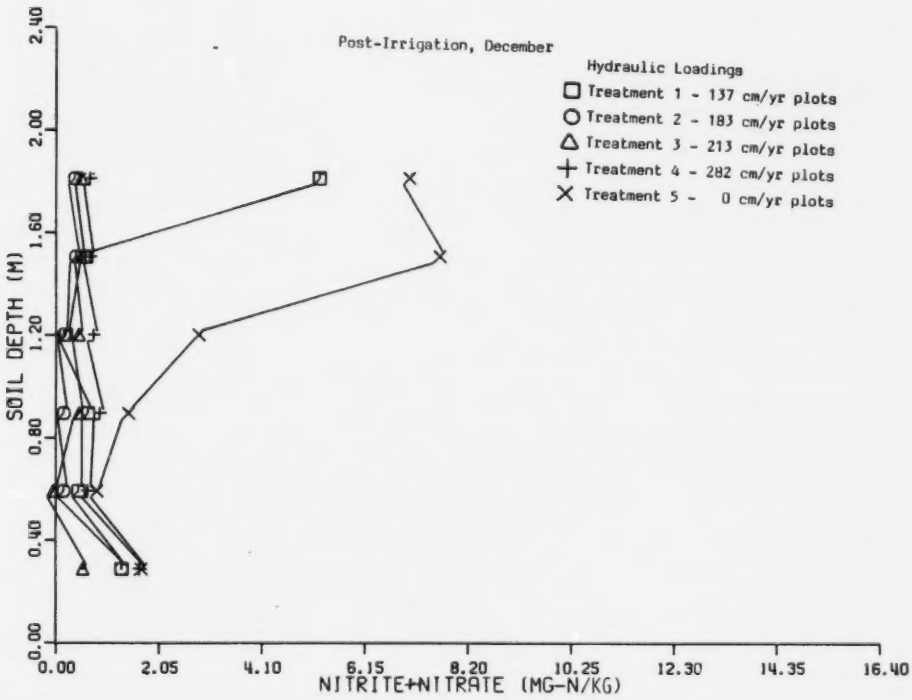


Figure 7. Nitrite plus Nitrate in Soil Beneath Trial 15000 Grain Sorghum plots, 1983

C_{ir} = Nitrogen concentration in irrigation water (mg/l),

C_p = Nitrogen concentration in precipitation (mg/l),

Q_{ir} = Amount of irrigation (cm/yr),

Q_p = Amount of precipitation (cm/yr),

e = Fraction of nitrogen applied by irrigation entering the soil profile,

a = Runoff coefficient,

g = Gas loss coefficient for applied inorganic N, fertilizer,

d = Gas loss coefficient of applied organic N fertilizer,

k_{m1}, k_{m2}, k_{m3} = Mineralization rate constants (yr^{-1}),

t = Time, and

k = Conversion coefficient (0.1).

Ammonia was the primary nitrogen form present in the irrigation water. Based on equilibrium conditions between ammonia and ammonium ion in water, approximately two percent free ammonia existed in the wastewater stream pumped to the Hancock farm at an average pH value of 7.76 at 20°C. The average pH of reservoir water was 8.30; therefore, approximately seven percent of the total ammonia was present as free ammonia at 20°C. Five percent of the total nitrogen applied by irrigation was assumed to be lost by ammonia volatilization and the factor, e, was 0.95. No surface runoff from any plot was experienced; consequently the runoff coefficient, a, was zero. Volatilization of ammonia forms within the soil profile were considered negligible; therefore, g and d were equal to zero. Furthermore, nitrogen input from nitrogen-fixing bacteria is normally minor in soils receiving wastewater (Loehr 1979) and N_{fn} was assumed negligible. Due to high CEC (>20) values in the soil profile at the Hancock farm, NH_3 nitrogen may have adsorbed on the soil matrix before it could escape to the atmosphere (Ryden 1981; Fenn 1975; Gasser 1969). Ammonia volatilization probably was minimal within the soil profile. Based on the preceding assumption, equation (2) reduces to the following form:

$$N_{ior|t} = N_{ior|t-1} + K(e.C_{ir}.Q_{ir} + (1)C_pQ_p) \quad (3)$$

$$+ (1-e^{km3t})N_{or|t-1}.$$

The mineralization rate constant (km3) was assumed to equal 0.02 yr^{-1} for the irrigated plots and 0.0052 yr^{-1} for the non irrigated plot. The values for the parameters used in equation (3) are presented in Table D.1. Generally, only one to three percent of the soil organic matter is mineralized during a growing season (Bremner 1967). The amount of denitrified nitrogen, N_d, was computed by the following expression:

$$N_d = C(N_{ior|t}) \quad (4)$$

Where

C = denitrification coefficient (0.30).

The amount of nitrogen taken up by plants is presented in Table D.7. The mass balance was developed assuming no deep percolation of inorganic nitrogen through the profile; therefore the amount of inorganic nitrogen present in the profile was calculated as:

$$N_{ior|net} = N_{ior|t} - N_d - N_{cp} \quad (5)$$

Where

$N_{ior|net}$ = inorganic remaining in soil profile (kg/ha-yr), and

N_{cp} = Average nitrogen uptake by crops, (kg/ha-yr).

Figure 8 presents the predicted and average measured mass of inorganic nitrogen within the upper 183 cm of the soil profile in the fall 1983. The low nitrogen removal by the crop on the plot receiving no irrigation was reflected in no grain produced by the crop. Stalk and leaf tissues were the only vegetation grown. As anticipated, the nitrogen balance for the non-irrigated plot indicated practically no deep percolation of nitrogen past 183 cm depth. Nitrogen losses were attributable to crop uptake and mineralization. Virtually all the organic nitrogen mineralized

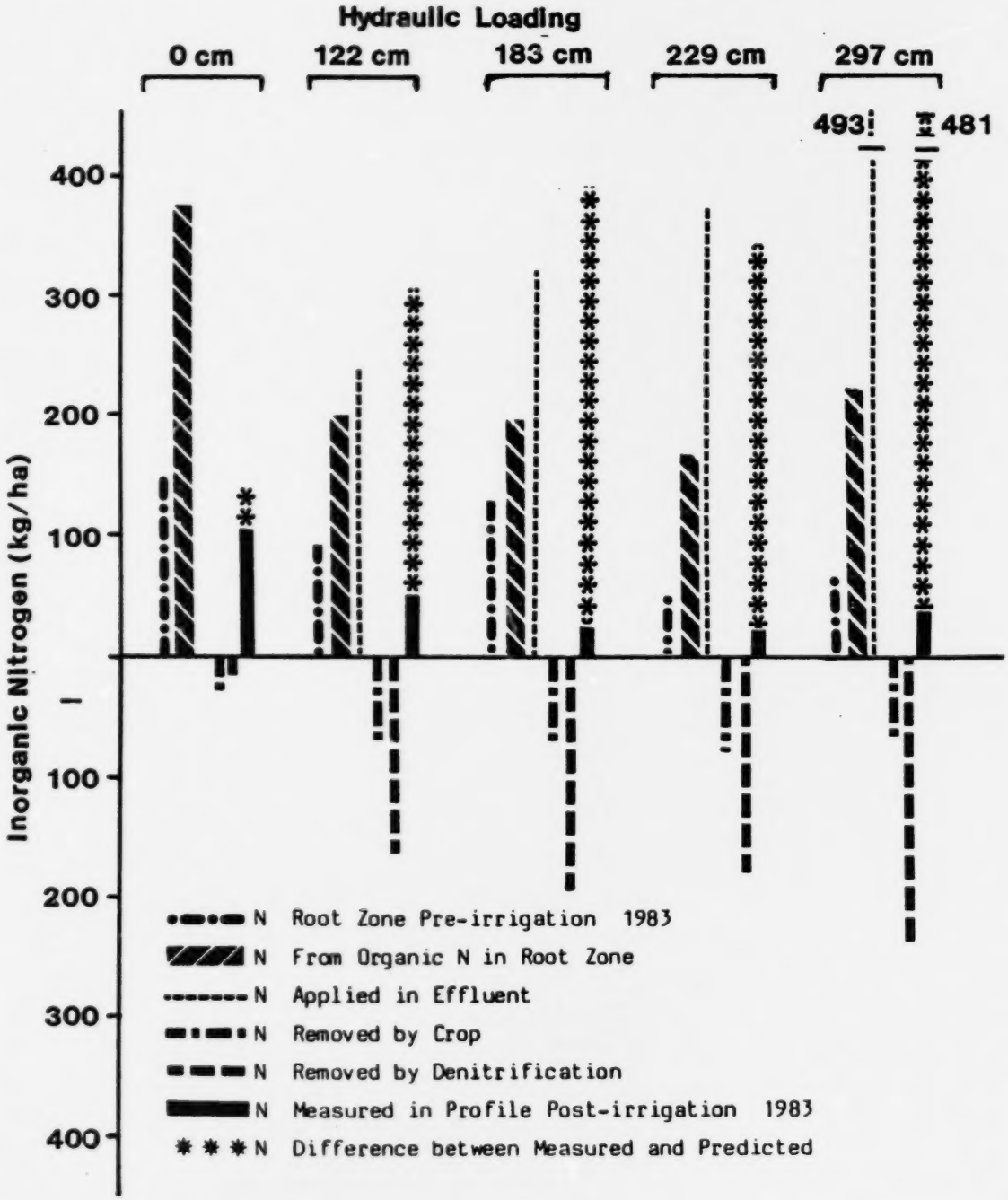


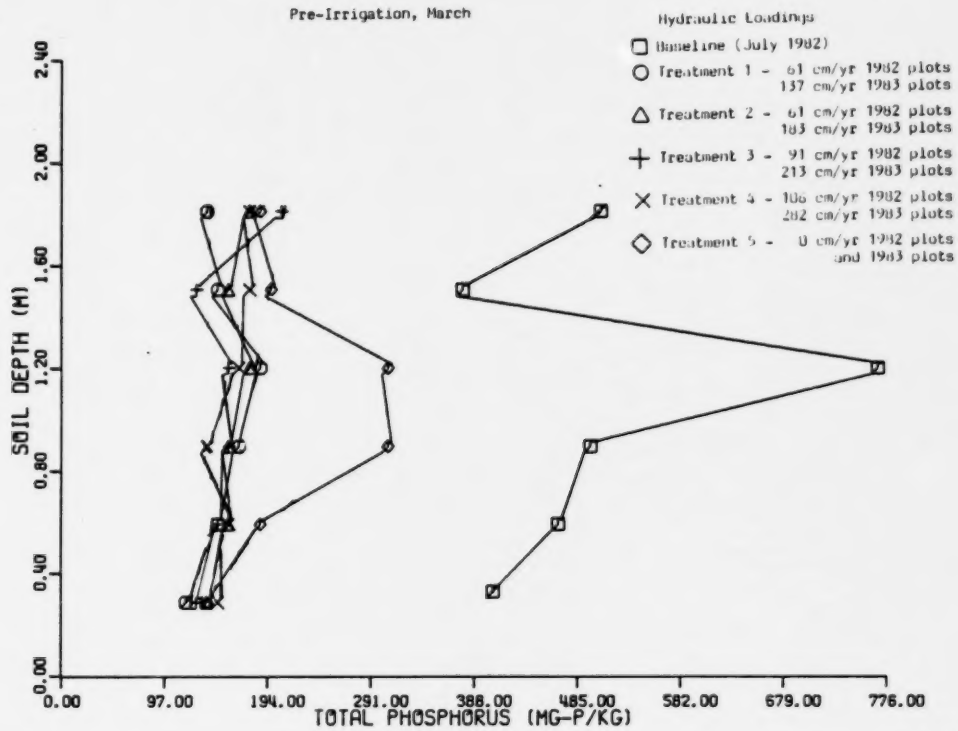
Figure 8. Nitrogen Mass Balance for Trial 15000 Grain Sorghum plots

from March 1983 to December 1983 was removed from the soil profile by these two processes.

The nitrogen mass applied to the irrigated plots exceeded the mass removed by the crop. The amount of unaccounted nitrogen mass and the uniform NO_3 concentration within the 183 cm profile in December 1983 (Figure 8) strongly imply a major loss of nitrogen through deep percolation. The spacial variability of the data in conjunction with the assumptions imposed on the model were sources of error in the model predictions.

Phosphorus--Organic and inorganic phosphorus forms in soils are relatively insoluble. Much of the organic phosphorus is slowly mineralized due to the adsorption of phosphate containing substrate to metal complexes (Alexander 1967; Loehr 1979). At low phosphate levels surface sorption is the dominant factor in removing phosphorus from the soil solution. Calcite, kaolinite, montmorillonite, and hydrous oxides of iron and aluminum adsorb phosphate phosphorus. The fine textured, alkaline, calcareous soils at the Hancock research site suggest phosphate-calcite reactions as the dominate factor removing phosphorus from the soil solution. In alkaline soils, however, the existence of amorphorus hydrous oxides as coatings may decrease the importance of adsorption of phosphorus by calcite (Shukla et al 1971; Holford and Mattingly 1975). Nonetheless, the existence of an indurated caliche soil ($CaCO_3$ soils) at the 45 cm to 183 cm depth in the soil profile supports the hypothesis that phosphate-calcite reactions were most likely a major factor in the removal of phosphorus from the soil solution. Figure 9 shows the concentration of total phosphorus (TP) within the soil profile.

The level of TP within the soil profile decreased from the concentrations measured in the baseline samples. Baseline soil cores were collected over the entire area of each Trial and composited; whereas, during the remainder of the project, soil cores obtained from each treatment in a Trial were collected from within the area of each replicate plot and composited. Consequently, decreases in TP concentrations in the soil profile may have been an artifact of the differences in sampling procedure employed in 1982. During 1982, no major precipitation events occurred after the



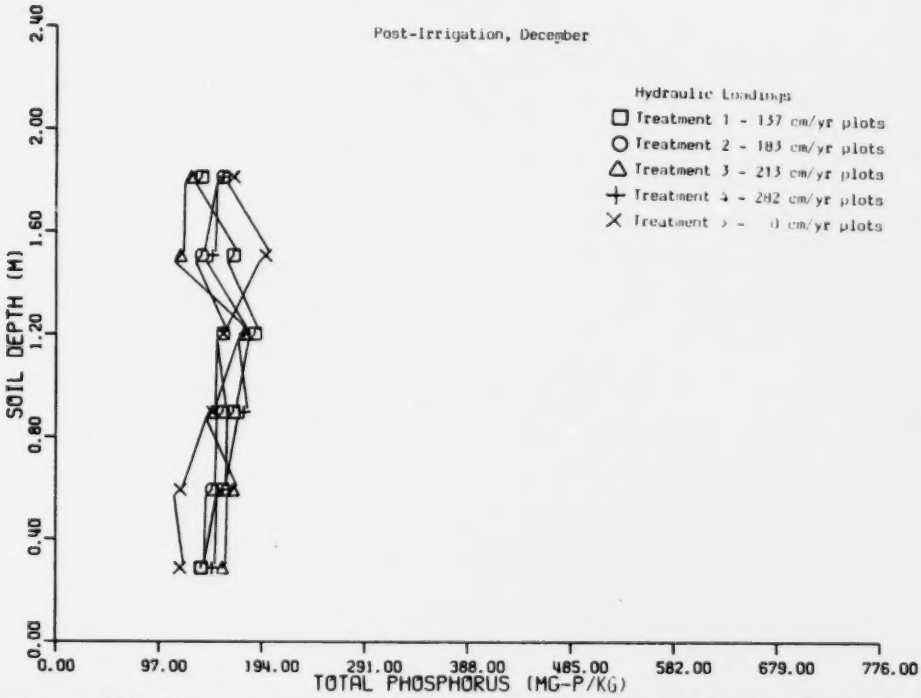


Figure 9. Total Phosphorus in Soil Beneath Trial 15000 Grain Sorghum plots, 1983

baseline samples were collected in July. Soils collected from the irrigated plots exhibited a relatively uniform TP concentration profile ranging from 120 to 190 mg-P/kg in March 1983 and December 1983. The non-irrigated plot (Treatment 5) showed higher levels of TP at the 91 cm (310 mg-P/kg) and 122 cm (310 mg-P/kg) depth than detected in the irrigated milo plots in March 1983. In December 1983, TP levels measured in all soil samples collected from the milo test plots were relatively equivalent (Figure 9).

Organic phosphorus comprised 69 percent of the total phosphorus in the 183 cm soil core extracted in July 1982. In March 1983, after the first growing season and the torrential rains and flooding experienced in

TABLE 10. ORGANIC P:TOTAL P RATIO
IN TRIAL 15000 GRAIN SORGHUM PLOT SOIL

Treatment	Hydraulic Loading (m/yr)	1982 July	1983 March	1983 December
Baseline	0.00	0.69		
1	1.37		0.28	0.32
2	1.83		0.26	0.29
3	2.13		0.26	0.33
4	2.82		0.29	0.37
5	0.00		0.17	0.17

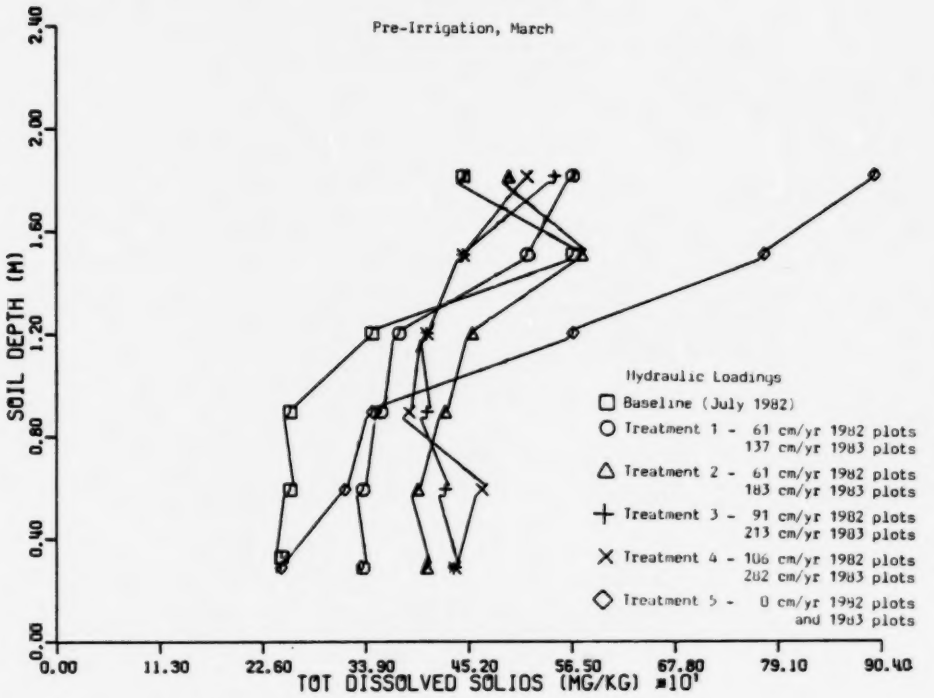
May and June 1982, the percentage of organic P contained in the soils collected from the irrigated plots decreased to an average of 27 percent of the total phosphorus (Table 10). The 183 cm soil profile in the irrigated plot contained 17 percent of the TP as organic P. Due to incorporation of organic matter (plant stalk, leaves, and roots) into the soil matrix, application of wastewater to the land and immobilization of inorganic phosphorus, the ratio of organic P to TP increased slightly (Table 10). Nonetheless, soil samples collected in 1983 indicated inorganic phos-

phorus as the major phosphorus form in 1983. A phosphorus mass balance was performed on the soils at each hydraulic loading (Table E-1).

In 1983, the mass of phosphorus removed by crops was less than applied. The amount of phosphorus removed by the irrigated grain sorghum was within the normal crop requirement of 15 kg/ha.yr (EPA 1981; A & L Soil and Tissue Analysis Handbook). The TP not accounted for in the mass balance in the irrigated plots ranged from an average concentration of 5 to 16 mg/kg within the 183 cm core at a bulk density of 1.4 g/cc. This error was probably well within the spacial variability of phosphorus in the test plots. Orthophosphate phosphorus (PO_4-P) was the primary phosphorus form applied to the land. Competing reactions by clay minerals, amorphous hydrous oxide and calcite probably limited the available phosphate to crops. The phosphorus remaining in the profile in December most likely was incorporated in relatively insoluble calcium forms (i.e., tricalcium phosphate and hydrooxyapatite). Phosphorus existing in these forms is not available to crops. Phosphorus may have also existed as dicalcium phosphate (Labile P) which will readily dissolve, should the solution P decrease, and become available to the crop.

Dissolved Solids--The variation of total dissolved solids through the soil profile is presented in Figure 10. Within the non-irrigated plots, salts began to accumulate in the lower 91 cm of the 183 cm in 1982. This TDS accumulation was diminished in the December 1983 soil core. Annual irrigation of 61 to 106 cm increased the TDS levels in the top 91 cm in 1982. Accumulation of salts was extended to the 122 cm depth by the end of 1983 (Figure 10). Mass balances of total dissolved solids indicate 84 to 99 percent of the TDS applied to the plots were transported beyond the 183 cm depth in 1983 (Table E.7).

Sodium (Na) was the major cation contained in the irrigation stream. With 80 percent of the irrigation derived from the reservoir water and 20 percent from water pumped directly from SeWRP, concentration of Na contained in the wastewater was approximately 307 mg/l in 1983. During 1982, with annual irrigation ranging from 61 cm to 106 cm, Na appeared to accumulate within the upper 31 cm (Figure 11). Increased irri-



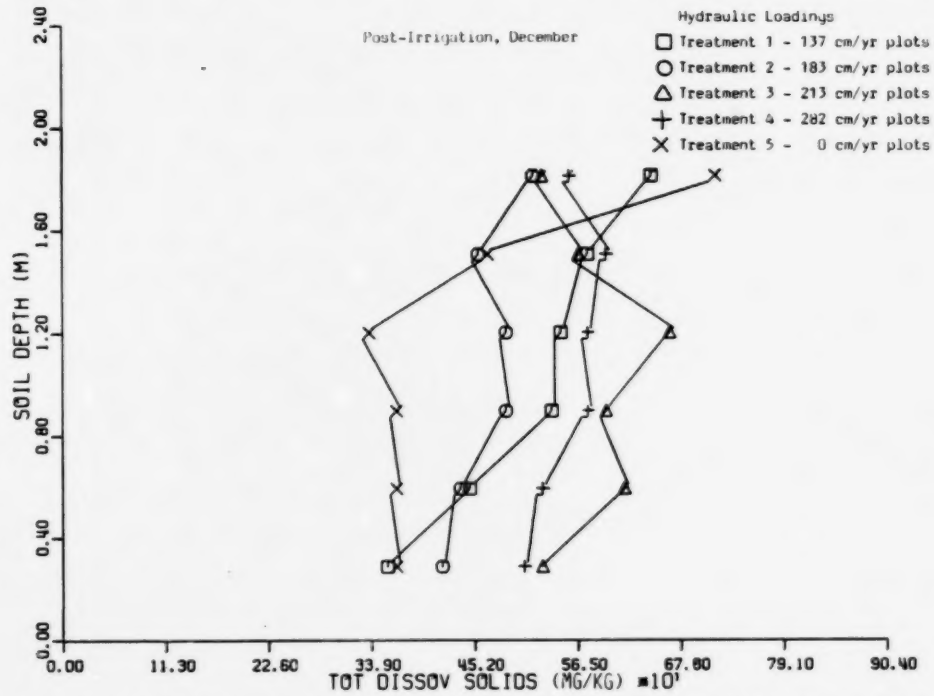


Figure 10. Total Dissolved Solids in Soil Beneath Trial 15000 Grain Sorghum plots, 1983

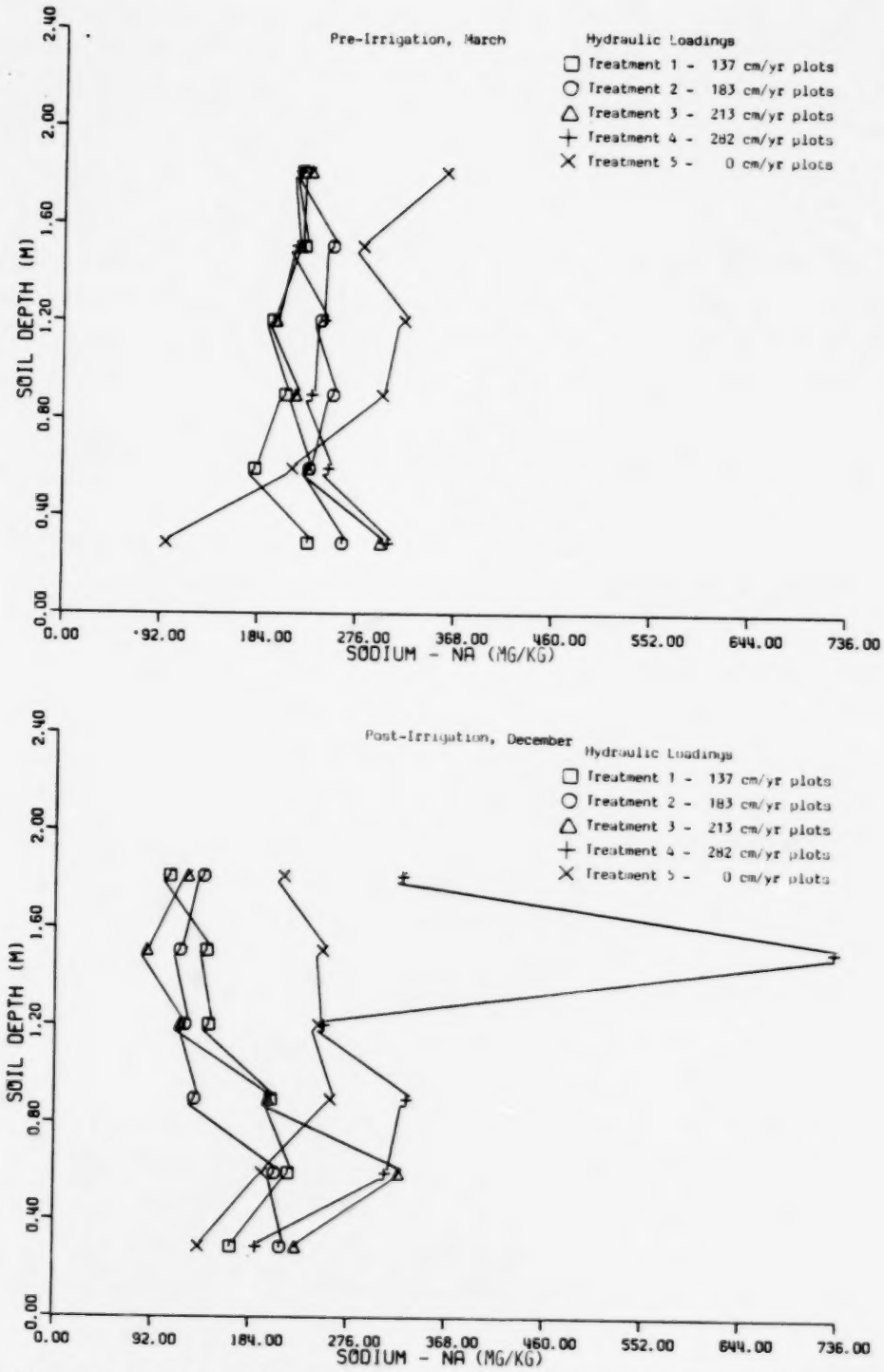


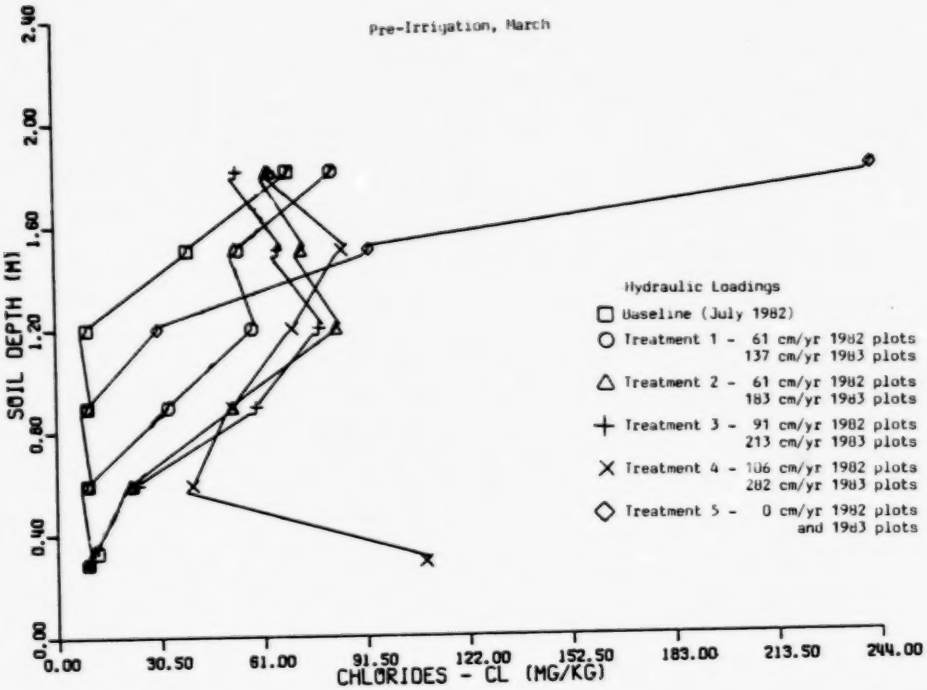
Figure 11. Sodium in Soil Beneath Trial 15000 Grain Sorghum Plots, 1983

gation during 1983 (137 cm/yr to 282 cm/yr) apparently leached Na from the soil profile and reduced Na levels in the lower 91 cm below concentration measured in March 1983. Soil cores extracted from Treatment 4 (282 cm/yr) plots exhibited an accumulation of Na at the 152 cm depth. Sodium mass balance for each treatment (Table E.13) indicated sodium was leached at each treatment in 1983.

The exchangeable Na percentage (ESP) computed for each 30 cm soil section is presented in Table F.2. The cation exchange capacity was calculated from available cation analysis of soils. Irrigation of the plots in 1982 increased the ESP primarily in the first 30 cm of the soil profile from 0.3 (non-irrigated plot) to a range of 2.0 to 4.6. During the 1983 growing season, increase in ESP occurred in the upper 61 cm of soil in plots irrigated with 137 cm and 183 cm. Annual hydraulic loadings of 213 and 282 cm produced higher ESP from 30 cm to 91 cm in the soil profile. Sodic soils have been arbitrarily defined as soils having an ESP of more than 15 percent exchangeable Na (Hausenbuiller 1972). Leaching of Na through the profile effectively minimized the establishment of sodic conditions within the soil profile.

As previously mentioned, Potassium (K) is a vital element in plant growth and is removed from the soil more than any other element except nitrogen. The crop failed to utilize the quantity of K applied to the soil through irrigation (Table E.19). More potassium than nitrogen was removed by the crops in the irrigated plots. Potassium to nitrogen ratios in the crop tissue ranged from 1.5 to 1.9. A potassium mass balance for each plot indicated that leaching of K passed 183 cm may have been the major removal mechanism.

Major anions associated with the salts applied to the soil were chloride (Cl) and sulfate (SO_4). In general, chloride levels increased with depth for the top 122 cm in the irrigated plots (Figure 12). Soils obtained from irrigated plots contained chloride concentrations ranging from 10 to 118 ppm which were within the normal range of .50 to 500 ppm detected in most soils (Hausenbuiller 1972). Chloride ions may be a substitute of fluoride in apatite; therefore, increased chloride levels at 122 cm to 183 cm may reflect this chemical composition. Chloride mass balances



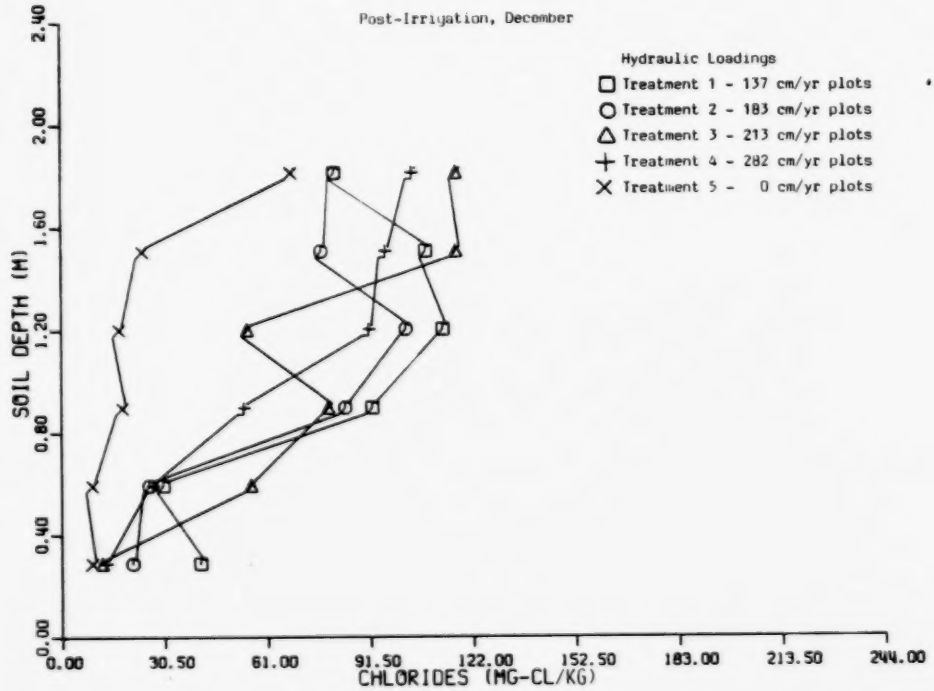


Figure 12. Chlorides in Soil Beneath Trial 15000 Grain Sorghum plots, 1983

(Table E.25) further substantiated the leaching of salts past a depth of 183 cm.

Sulfate ion also increased within the top 122 cm of the soil profile in soil cores obtained from the irrigated plots (Figure 13). Analysis of soils data obtained from the non-irrigated plots showed a lens of SO_4 ion present at 183 cm. With the existence of the indurated caliche layer, this SO_4 lens may be associated with gypsum ($CaSO_4$).

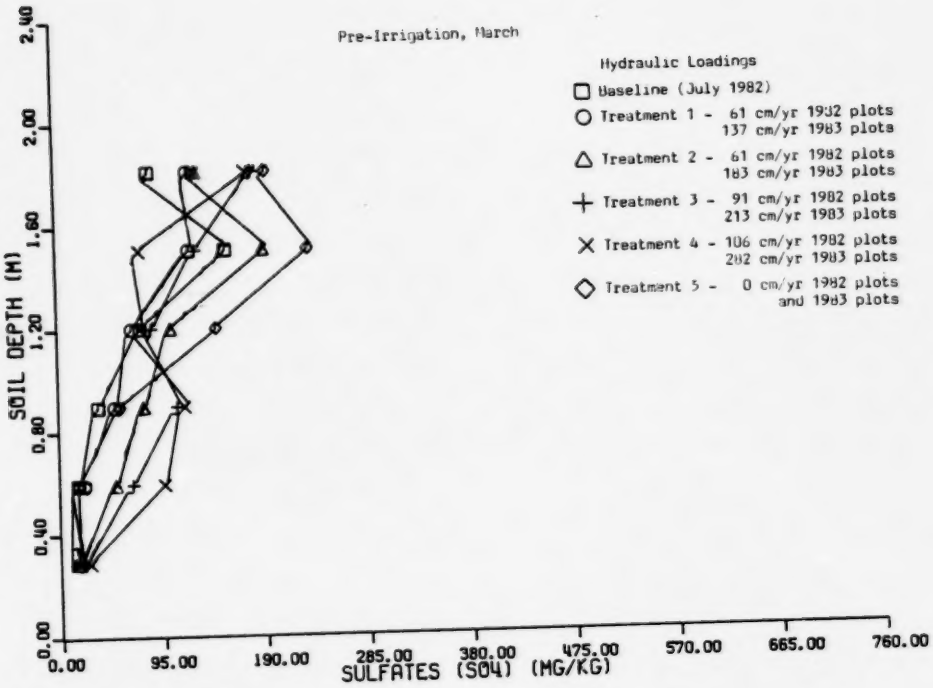
Cotton

Crop Quality--

Heavy precipitation (approximately 40 cm) in May/June 1982, necessitated replanting of cotton in July. Due to the late planting of the crop average lint production ranged from 63 to 213 kg/ha (Table 11). Irrigation of the crop resulted in vegetative growth with no increase in lint production. No significant differences ($\alpha = 0.05$) between cotton yields were determined for plots receiving 122 to 297 cm of municipal effluent per year or more in Trial 15000 in 1983.

Similar to results obtained from analysis of grain sorghum plant tissue, nitrogen in the cotton stalk tissue decreased in the 1983 crops (3510 to 10,300 ppm) compared to concentrations measured in 1982 crop samples (17,300 to 21,900 ppm). Nitrogen in seed tissue collected from irrigated plots in 1982 was, also, less than levels measured in 1983 samples (Table C.2). During 1983 the quantity of available nitrogen present in the soil solution was probably limited; consequently the nitrogen in the stalk tissue was translocated to the seed for protein synthesis. TKN levels in the seed tissue appeared to increase as hydraulic loading increased from zero to 50 cm/yr and decreased with great quantities of irrigation beyond 50 cm.

Greater phosphorus concentrations were detected in the seed than in the stalk tissue. Cotton plants grown in irrigated plots in Trial 14000 contained an average of 5.09 ± 0.29 mg P/g of seed compared to 6.20 ± 0.19 mg P/g of seed from Trial 15000 irrigated plots. Stalk tissue analyzed from Trial 14000 had more TP (2.42 ± 0.76 mg P/g) than tissue collected from Trial 15000 (1.15 ± 0.28 mg P/g). More phosphorus was transported to



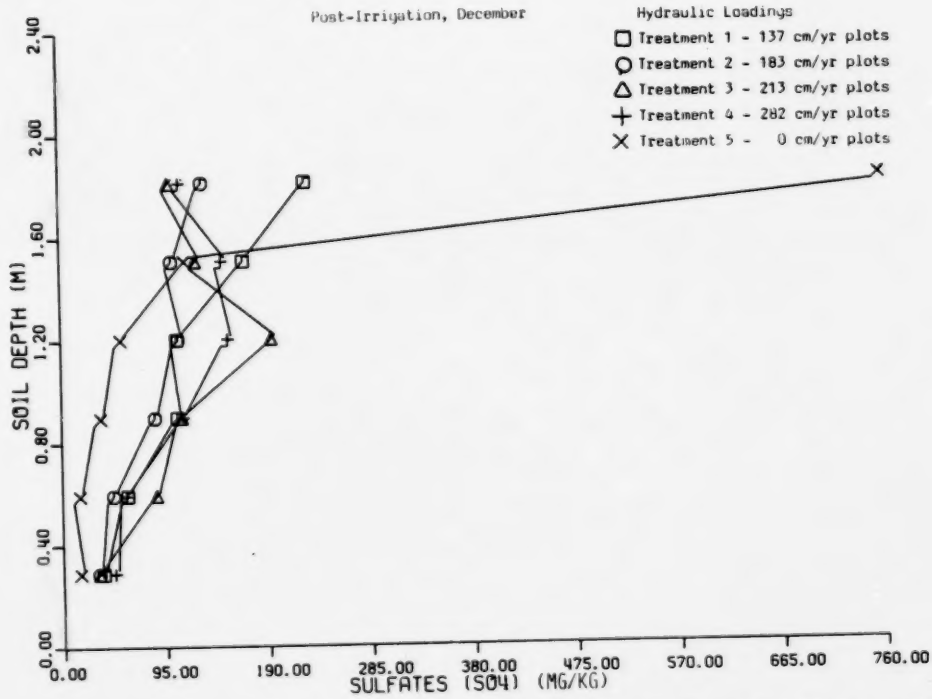


Figure 13. Sulfates in Soil Beneath Trial 15000 Grain Sorghum Plots, 1983

TABLE 11. COTTON LINT YIELDS FOR 1982 AND 1983 CROP IN TRIALS 14000 AND 15000

Trial	Treatment	Annual Hydraulic Loading (cm) 1982	Annual Hydraulic Loading (cm) 1983	Average Lint Yield (kg/ha) *(n) 1982	Average Lint Yield (kg/ha) (n) 1983
14000	2		0.		(2) 200. ± 71.
	4		20.		(2) 500. ± 283.
	6		41.		(2) 100. ± 71.
	8		51.		(2) 925. ± 318.
	10		61.		(2) 675. ± 177.
	12		69.		(2) 575. ± 460.
	14		86.		(2) 775. ± 813.
	16		102.		(2) 800. ± 354.
	18		122.		(2) 100. ± 0.
15000	5	0.	0.	(4) 213. ± 126.	(4) 638 ± 48.
	1	45.	122.	(4) 125. ± 45.	(4) 1300 ± 231.
	2	61.	183.	(4) 63. ± 39.	(4) 1538 ± 565.
	3	106.	229.	(4) 48.0 ± 38.	(4) 1438 ± 315.
	4	122.	297.	(4) 70.0 ± 98.	(4) 1425 ± 222.

*n = number of samples

the seed and lint tissue, thereby producing greater yields.

In Trial 15000, cadmium levels in crop tissue samples were less in 1983 (<0.05 ppm) than in 1982 (i.e., 0.07 to 0.10 ppm in stalk tissue and 0.16 to 0.23 ppm in seed). Cadmium levels were only 0.07 ppm or less in stalk tissue once annual hydraulic loadings were 86 cm or greater (Table C.2).

Soils--

Nitrogen--Nitrogen within the soil profile existed primarily in the organic form (Table D.9). Figures 14 and 15 present the variation in TKN through the soil profile in the cotton plots. Plots receiving annual irrigation of 41 cm or less exhibited relatively no change in TKN in the upper 61 cm of soil. Annual hydraulic loadings from 41 cm to 122 cm (Trial 14000) produced a reduction in TKN in the top 91 cm of the soil profile (Figure 14). No apparent accumulation of TKN occurred within the 183 cm soil cores extracted from test plots receiving 122 cm/yr to 297 cm/yr in 1983 (Figure 15).

Carbon to nitrogen ratios ranged from 5.65 to 37.51. Soil samples collected in the spring 1983 had C:N ratios from 5.65 to 19.7 indicating net mineralization of organic nitrogen occurred during this time period. After the 1983 growing season C:N ratio ranged from 11.36 to 37.51. In Trial 14000, plots receiving annual hydraulic loading rates of 51 cm (Treatment 8) to 122 cm (Treatment 18) contained C:N ratios of approximately 20 to 37 within the upper 91 cm of soil. This increase in carbon to nitrogen mainly reflects the decrease in organic nitrogen in the profile which occurred during the 1983 irrigation season. Net immobilization of nitrogen would dominate nitrogen transformations within treatments during this sampling period.

Soil nitrite plus nitrate-nitrogen increased within the top 30 cm in plots irrigated with 20 and 41 cm/yr (Figure 16). Soil collected from cotton test plots in Trial 14000 irrigated with 51 to 122 cm/yr contained less NO_2 + NO_3-N levels within the first 91 cm than plots receiving less irrigation (Figure 16).

In Trial 15000, irrigated plots contained less than 3 mg NO_2 + NO_3-N

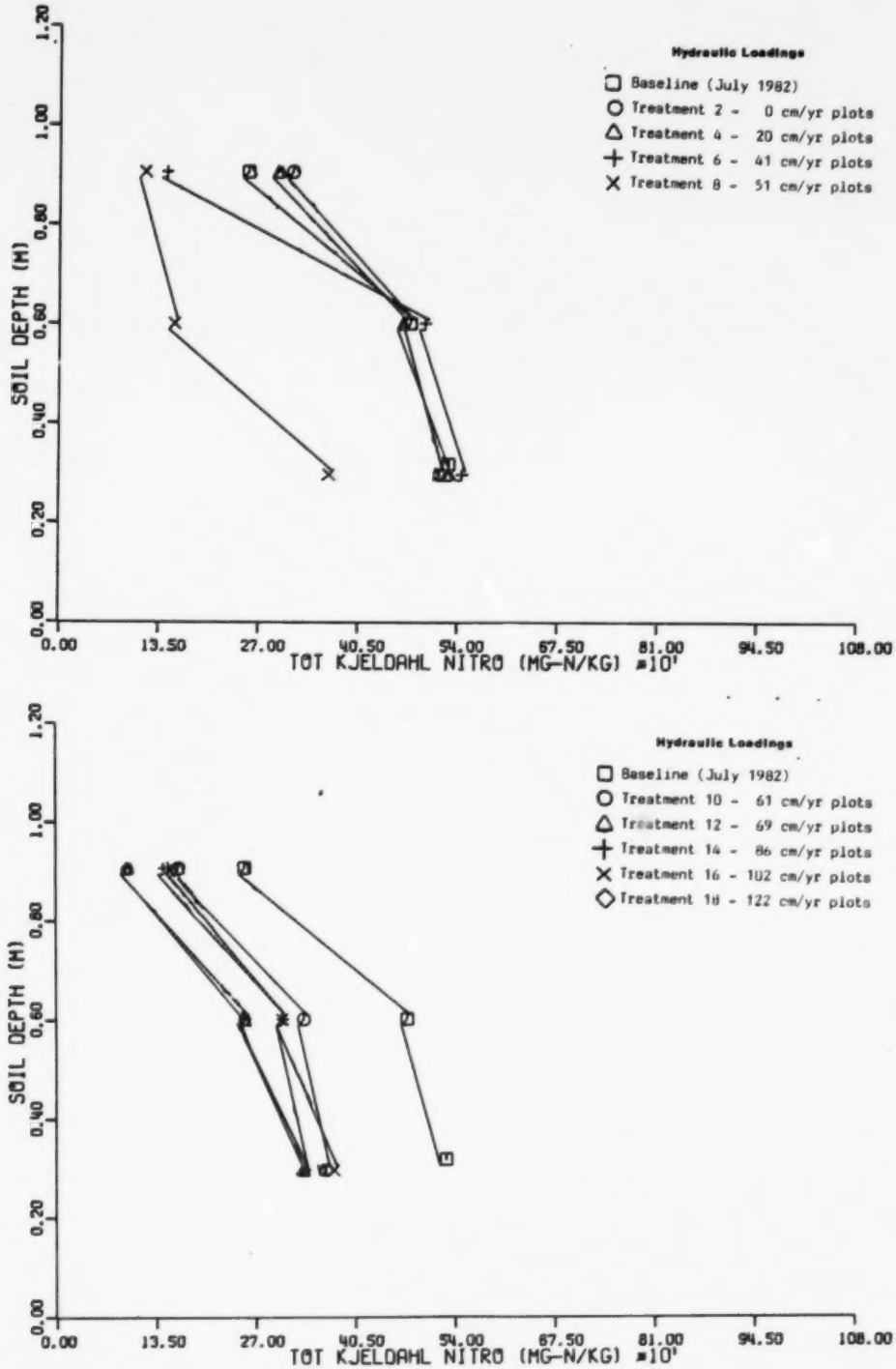
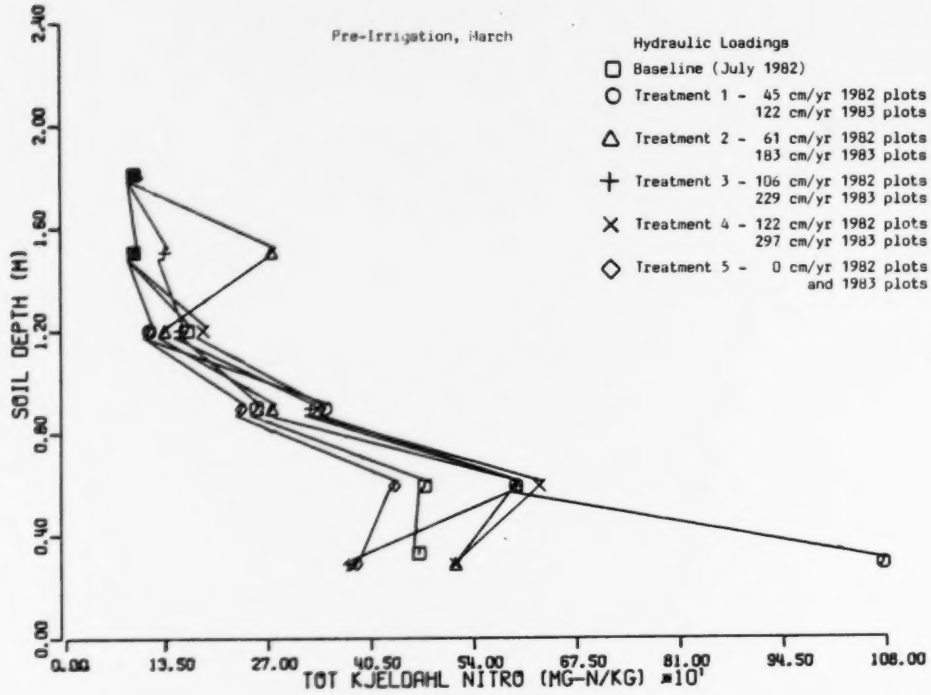


Figure 14. Total Kjeldahl Nitrogen in Soil Beneath Trial 14000 Cotton plots, Post-Irrigation, December 1983



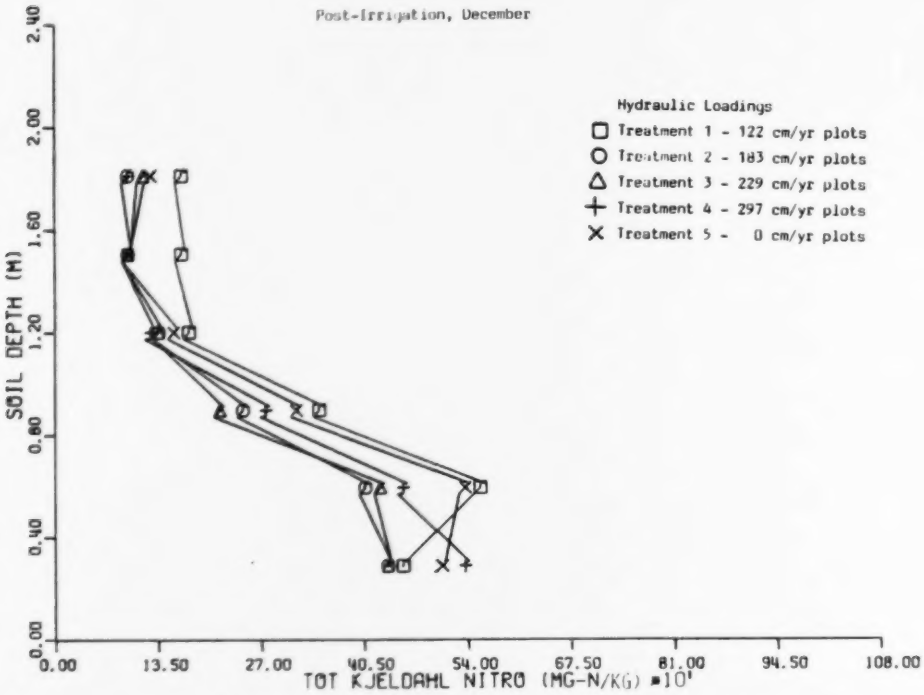
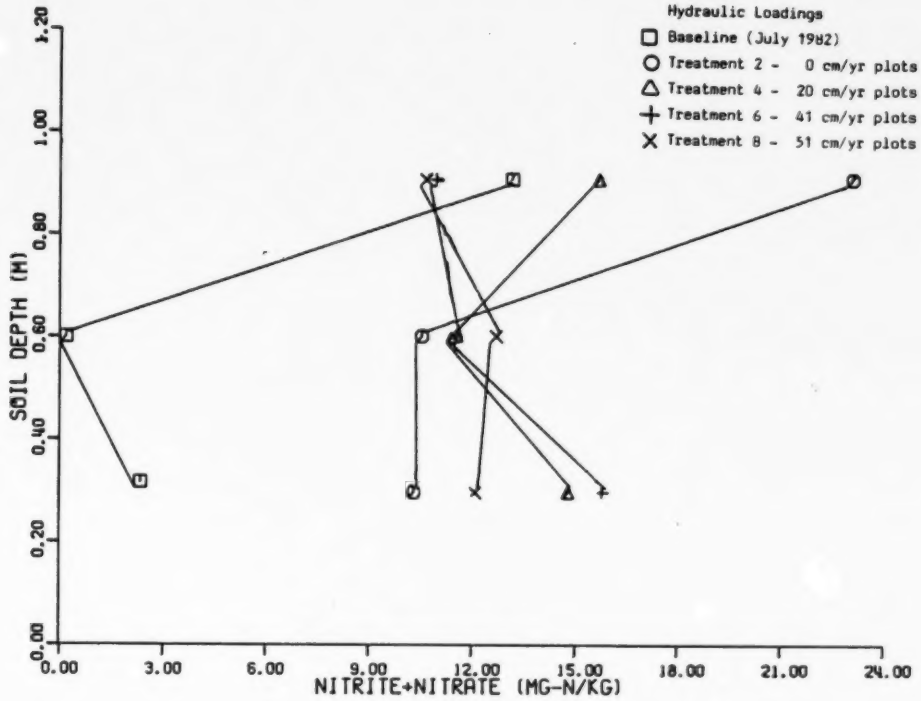


Figure 15. Total Kjeldahl Nitrogen in Soil Beneath Trial 15000 Cotton plots, 1983



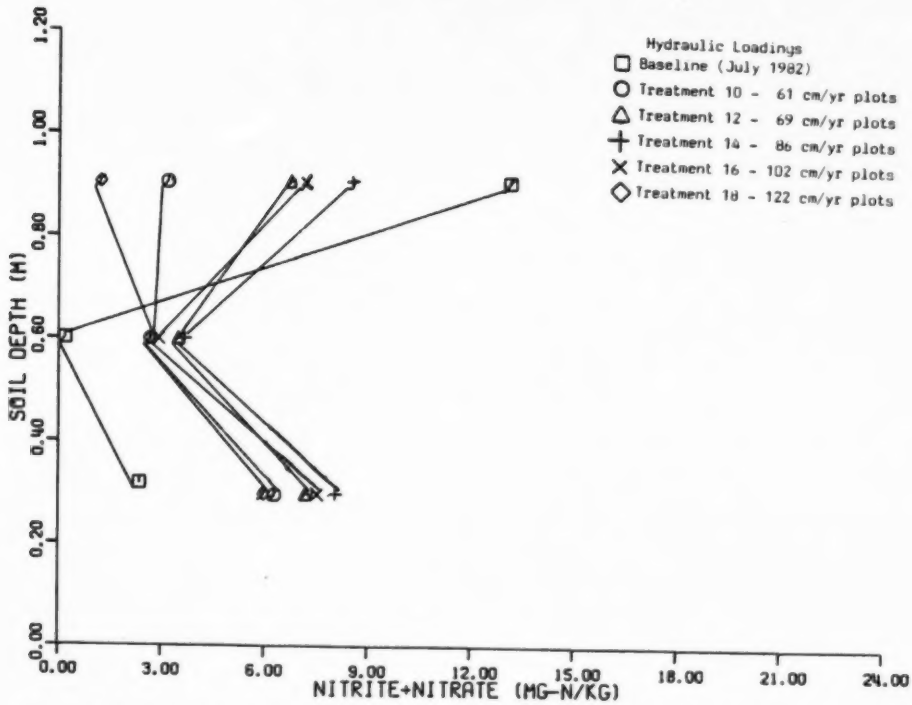
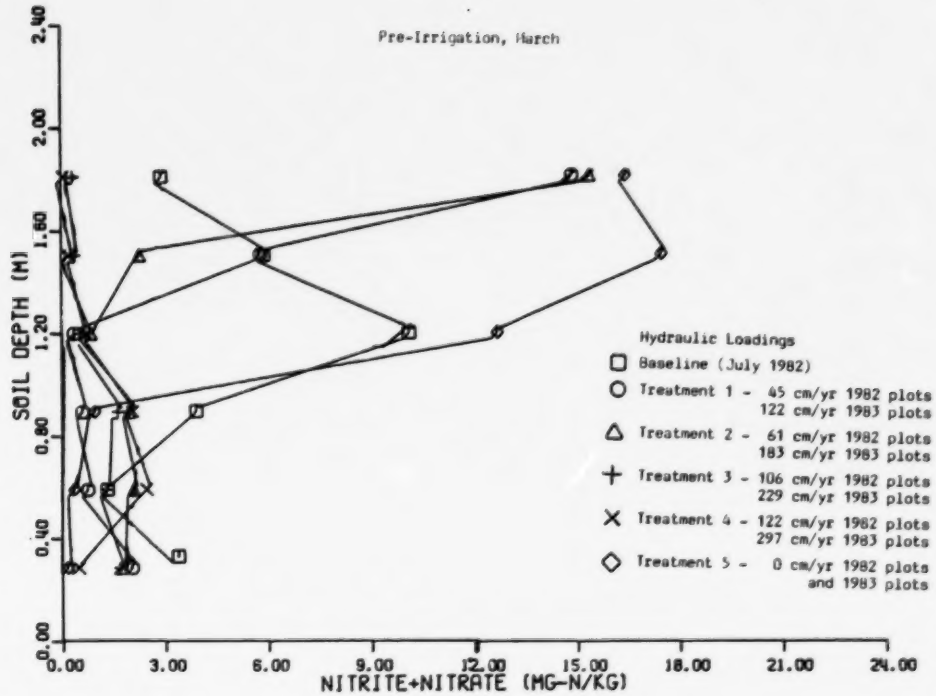


Figure 16. Nitrite plus Nitrate in Soil Beneath Trial 14000 Cotton plots, Post-Irrigation, December 1983

per gram of soil in the upper 122 cm of the soil profile (Figure 17). Prior to the 1983 irrigation season the lower 61 cm of soil collected from Trial 15000, treatments 1 and 2, contained NO_2 + NO_3-N lens (Figure 17). These NO_2 + NO_3-N accumulations were not measured in soil samples collected after the 1983 growing season (Figure 17).

Nitrogen mass balances were conducted on each test plot. The parameter and coefficient values used to solve equation (3) are presented in Table D.2. The cotton crop consumed 29.3 to 157.2 kg-N/ha from the soil solution (Table D.8). Except for nitrogen uptake by cotton receiving annual irrigation of 20 and 51 cm, the crop utilized less N than applied through irrigation. Treatment 1 (122 cm/yr) in Trial 15000 produced a crop which removed 103.5 kg-N/ha compared to 32.8 kg-N/ha consumed by cotton produced in Treatment 18 (122 cm/yr), Trial 14000. Higher concentrations of organic nitrogen (i.e., 8629 kg-N/ha compared to 5369 kg-N/ha) in the upper 91 cm of the soil profile may have provided a slower release of inorganic N which was more readily available to the crop for extended periods of time. Within the top 30 cm, 1075.5 mg-N/kg was measured in Trial 15000, Treatment 1 compared to 519.3 kg-N/ha within the same soil depth in Treatment 18, Trial 14000.

Figures 18 and 19 present the results of the N mass balance. Mechanisms governing the transport of N within the initial 91 cm of the soil profile in Trial 14000, treatments 2, 4, and 6 were mineralization of organic nitrogen, crop uptake, and denitrification. Inorganic nitrogen accumulated within the top 91 cm of soil. Test plots receiving 51 cm of water exhibited an increase of inorganic nitrogen during the 1983 growing season. The nitrogen model adequatly predicted the inorganic N present in the soil profile after the growing season. An annual assumed three percent mineralization of organic nitrogen, however, was less than the measured conversion of approximately 50 percent. Potential error due to spatial variability in composite soil core defining soil characteristics prior to the 1983 growing season probably contributed to a certain amount of the apparent reduction in organic nitrogen. Inorganic N was leached beyond 183 cm depth in test plots irrigated with 122 cm/yr of effluent or more (Figure 19). Based on the values presented in Table D.2, inorganic



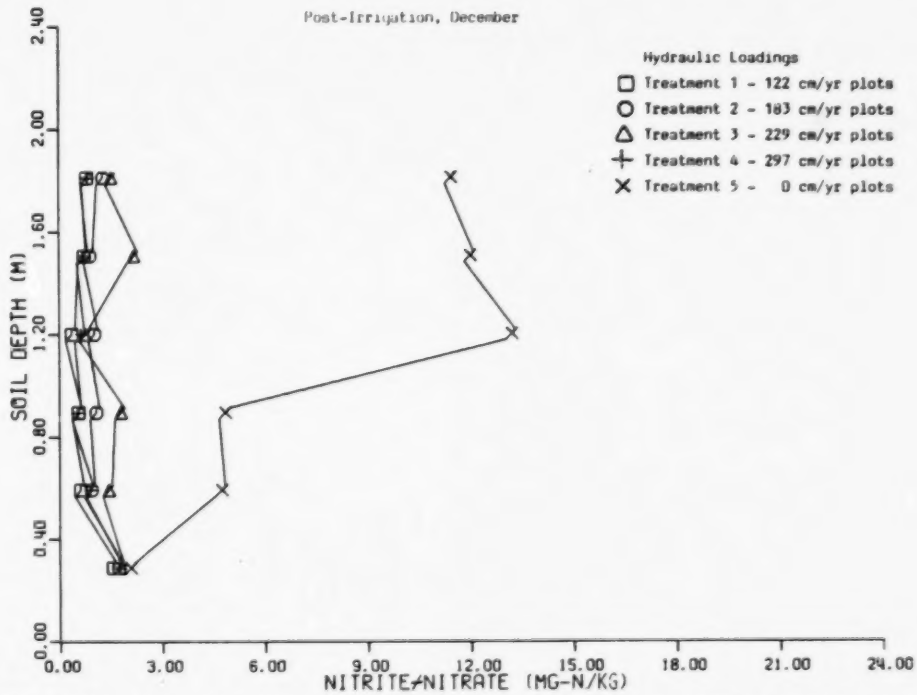


Figure 17. Nitrite plus Nitrate in Soil Beneath Trial 15000 Cotton plots, 1983

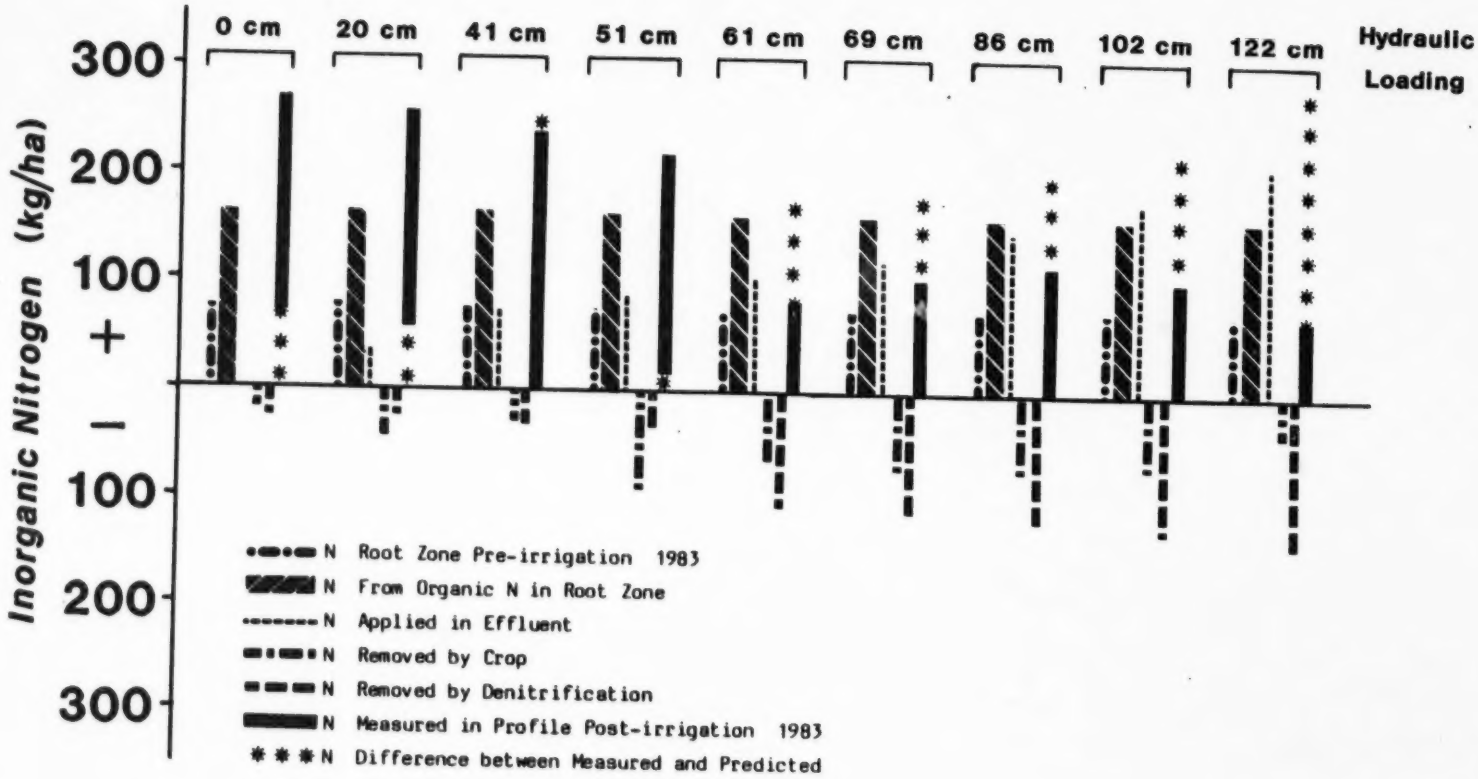


Figure 18. Nitrogen Mass Balance for Trial 14000 Cotton plots

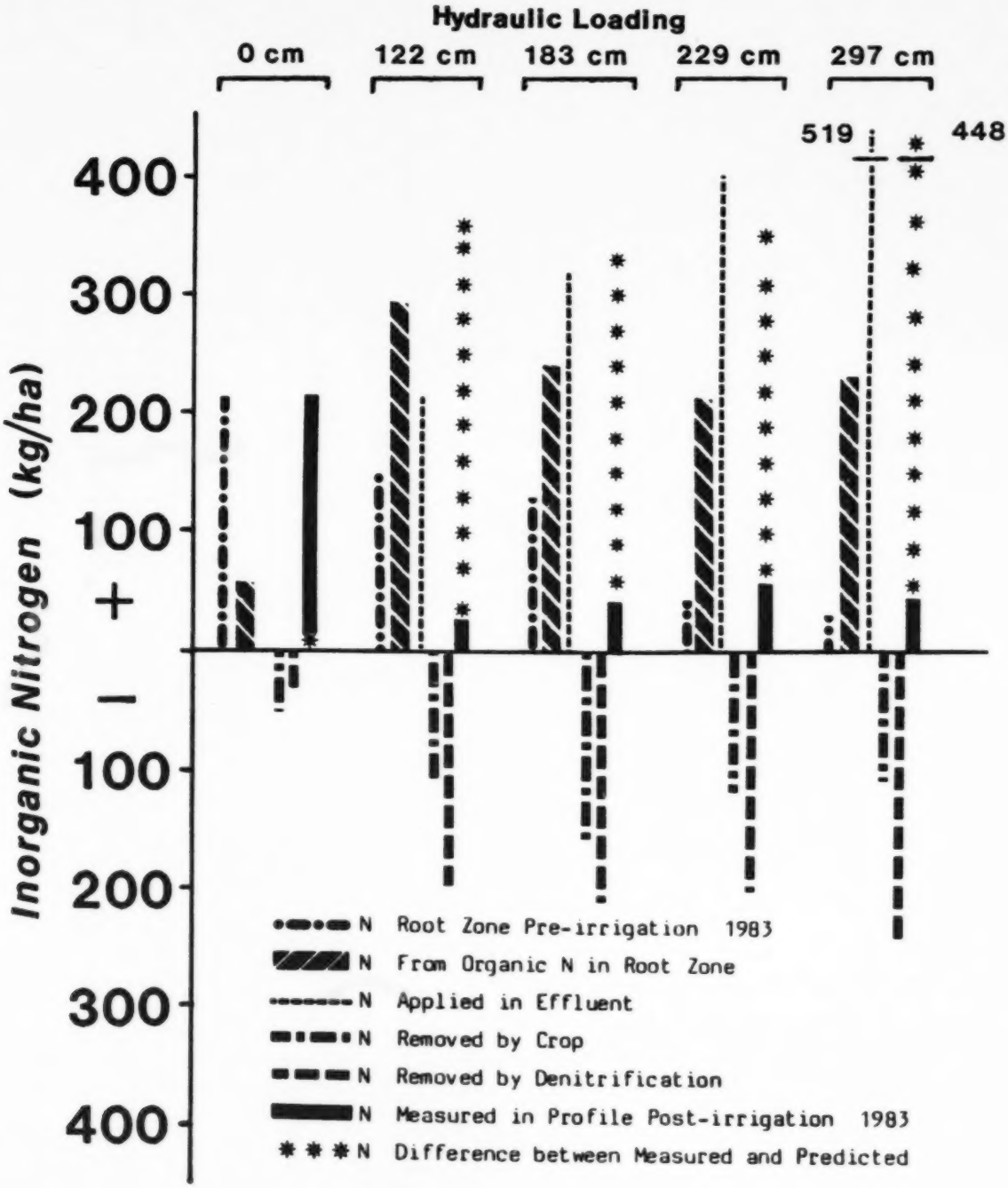


Figure 19. Nitrogen Mass Balance for Trial 15000 Cotton Plots

nitrogen was transported below 91 cm in plots receiving 61 cm or more irrigation. Since the major transport of nutrient into the crop occurs within the top 61 cm of soil, decreasing quantities of nitrogen present in the profile below 91 cm are removed from the soil matrix by crop consumption.

Total carbon to total nitrogen ratios within the soil profile were generally greater than 10. Maximum denitrification of nitrate nitrogen (NO_3-N) has been observed at a C:N ratio between 2 and 3 (Ryden 1981). Therefore, available carbon may have limited the denitrification process and deep percolation of NO_3-N may have been the major mechanism for nitrogen removal at depths greater than 91 cm. Mineralization of organic N present in the profile appeared to be the primary mechanism for accumulation of inorganic nitrogen in the soil at annual hydraulic loadings less than or equal to 51 cm. The results indicated that in 1983, 51 cm or less provide sufficient N through irrigation to satisfy the crop nitrogen requirement without transport of nitrogen below 91 cm. The design hydraulic loading of the Hancock land application system was 66 cm/yr.

Phosphorus--Soil phosphorus concentrations were quite uniform through out the entire 183 cm depth (Figures 20 and 21) of Trials 14000 and 15000. Total residual phosphorus in the soil after the crop harvest did not appear to be a function of phosphorus mass loading. Inorganic P comprised the major phosphorus form in the soil profile (Table E.30). Due to the fine textured, alkaline, calcareous soils, calcite-phosphorus interaction most likely governed the relation of inorganic phosphorus within the soil and the phosphorus availability to crops.

Phosphorus mass consumed by the cotton did not equal the quantity applied through irrigation (Table E.2). The mass of phosphorus available to the crop appeared to be less in Trial 14000 compared to the quantity of phosphorus removed by cotton in Trial 15000. Furthermore, the mass balance indicated possible leaching of dissolved phosphorus beyond 183 cm in all treatments of Trial 15000, whereas accumulation of phosphorus within the upper 91 cm of the soil profile was detected in test plots receiving phosphorus mass loading of 75.6 kg-P/ha or less. In Trial 14000, phos-

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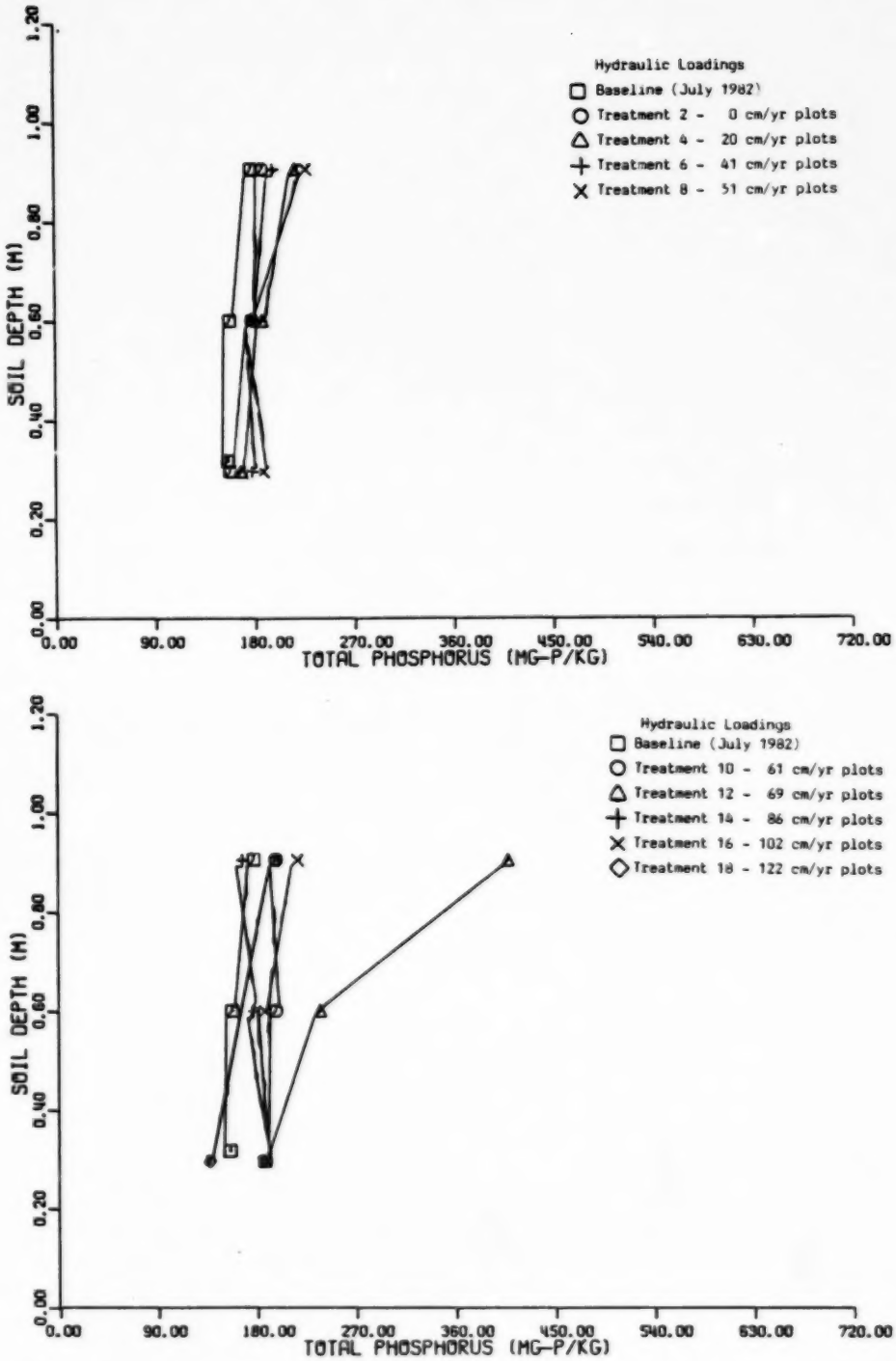
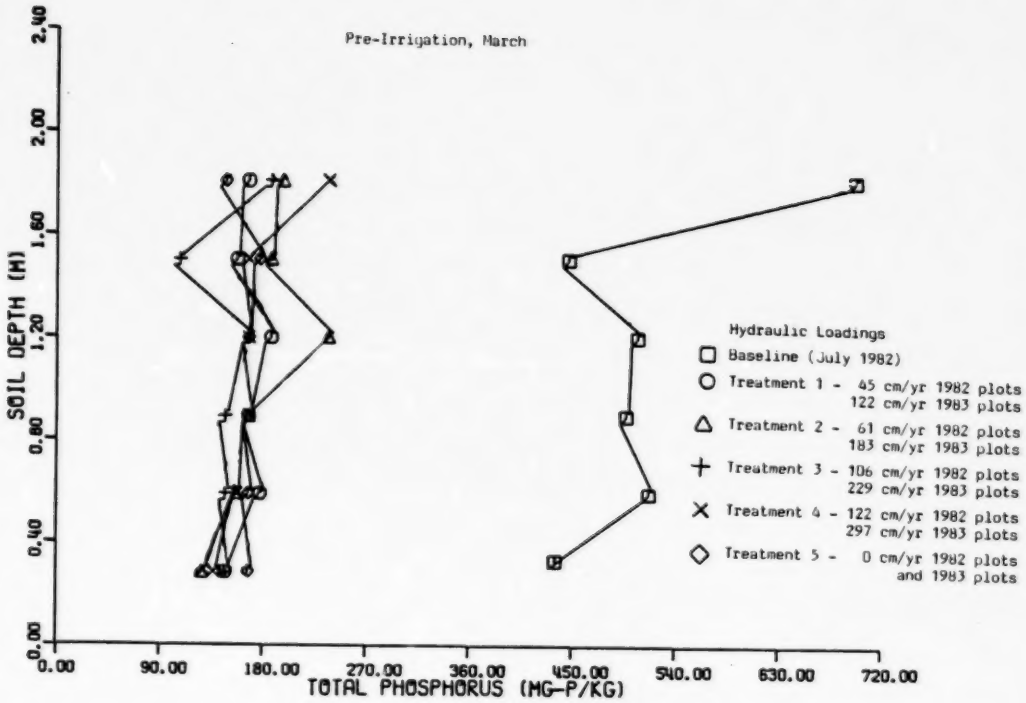


Figure 20. Total Phosphorus in Soil Beneath Trial 14000 Cotton Plots, Post-Irrigation, December 1983



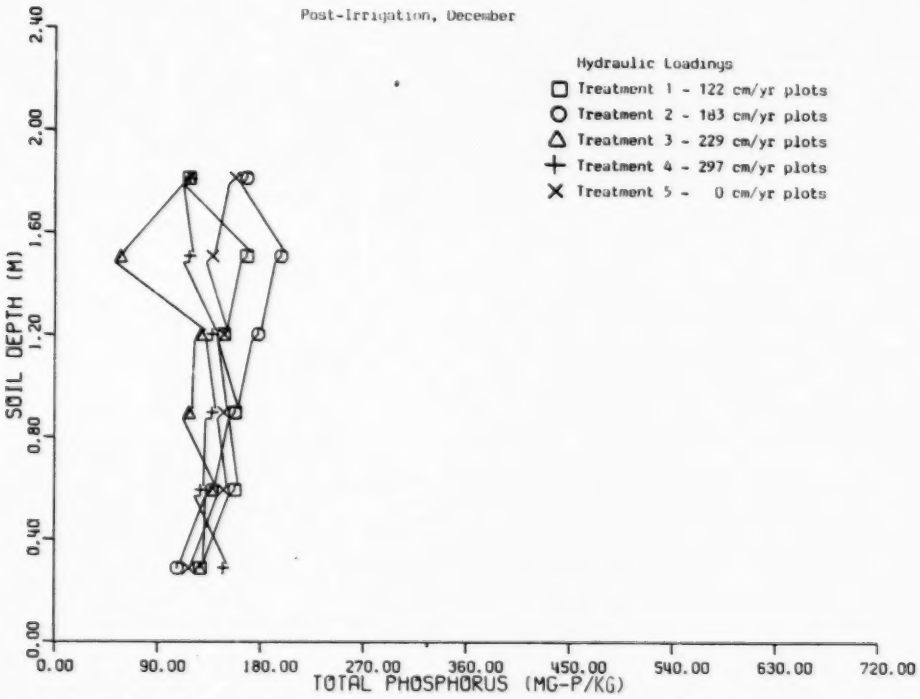


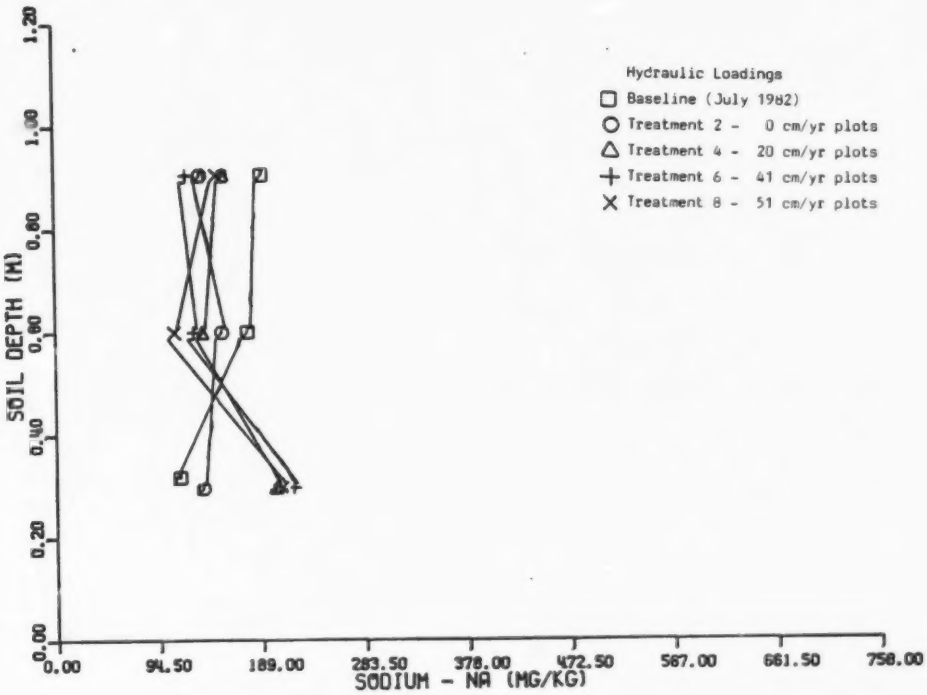
Figure 21. Total Phosphorus in Soil Beneath Trial 15000 Cotton Plots, 1983

phorus uptake by cotton was less than the cited value of 15 kg/ha.yr (EPA 1981; A & L Agricultural Laboratories, Inc. Soil and Plant Analysis Handbook).

Dissolved Solids--Figures E.1 and E.2 show the variation in total dissolved solids (TDS) through the soil profile in each test plot. In Trial 14000 the non-irrigated plot exhibited a TDS increase within the upper 91 cm in 1982 (Figure E.1). As the annual hydraulic loading increased the TDS concentration within the top 61 cm increased to a maximum of 720 mg/kg (Trial 14000, Treatments 12, 14, and 16; Trial 15000, Treatment 3). Accumulation of TDS was observed at depths of 152 cm and 183 cm in Trial 15000, Treatment 4 (297 cm/yr). In general, during the 1983 irrigation season, TDS increased in the upper 122 cm of soil in all irrigated cotton test plots. Salts were leached from the top 91 cm of soil in test plots irrigated with 41 cm/yr and greater (Table E.8). Deeper percolation of TDS beyond 183 cm probably occurred at annual hydraulic rates greater than 41 cm/yr.

Corresponding to the TDS increase in the top 31 cm was an increase in sodium (Na)(Figures 22 and 23). In Trial 15000 Na accumulated in the top 61 cm in all irrigated plots compared to only the upper 31 cm in the irrigated plots in Trial 14000. Soils extracted from Trial 15000, Treatment 4 (297 cm/yr) exhibited the greatest Na accumulation during 1983. Sodium appeared to have moved through portions of the soil profile of all irrigated cotton plots (Table E.14). The ESP changed in the upper 30 cm from 0.90 to a maximum percentage of 6.54 in Trial 14000 test plots (Table F.3). In the first 30 cm of soil, the ESP values ranged from 5.61 to 9.19 in samples obtained during the fall 1983. In Trial 15000, pre-irrigation soil samples at a depth of 30 cm had a computed ESP of 1.64 (Treatment 3) to 6.05 (Treatment 4). The ESP increased within tne top 61 cm of soil in all irrigated plots of Trial 15000. Sodic conditions in the top few centimeters of cotton plots irrigated with 183 cm/yr (ESP = 9.19) and 297 cm (ESP = 8.09) may have been created by high Na mass loadings.

Similar to potassium (K) consumption, by grain sorghum, cotton removed more K from the solution than nitrogen (Table E.20). A potassium



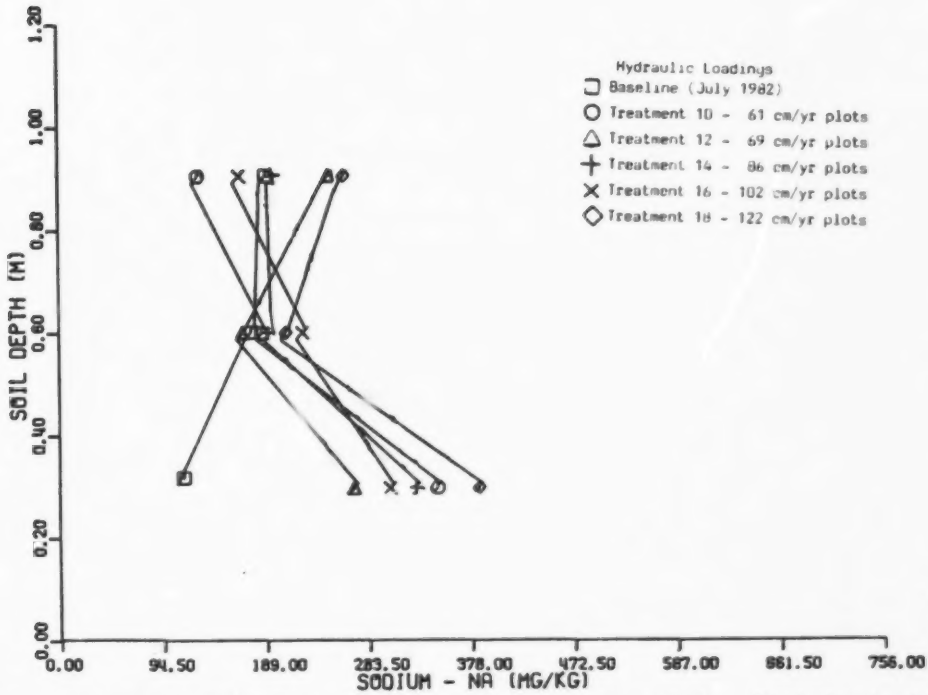
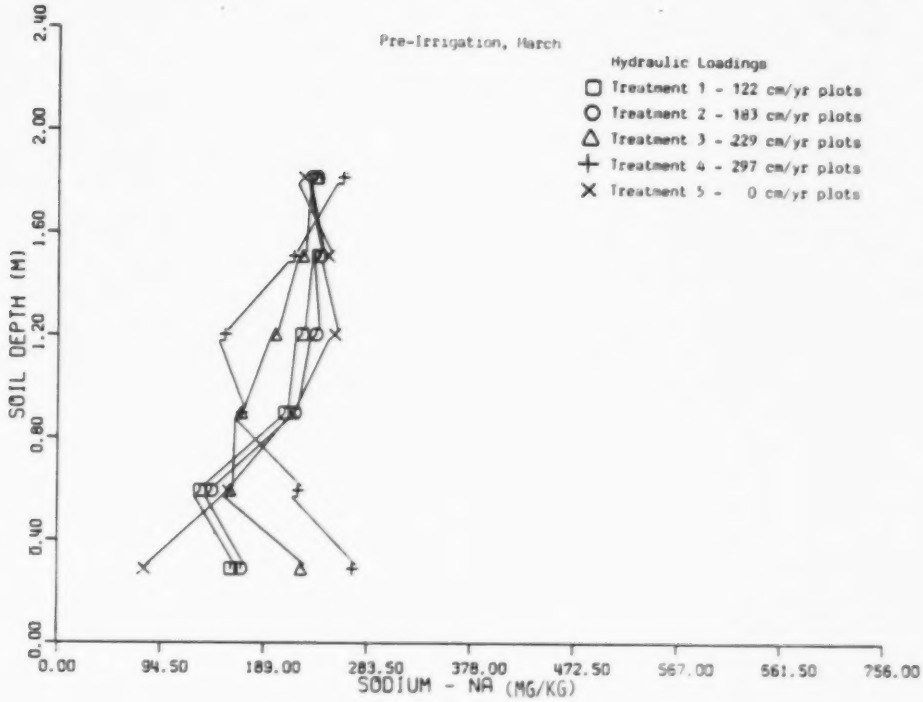


Figure 22. Sodium in Soil Beneath Trial 14000 Cotton plots, Post-Irrigation, December 1983



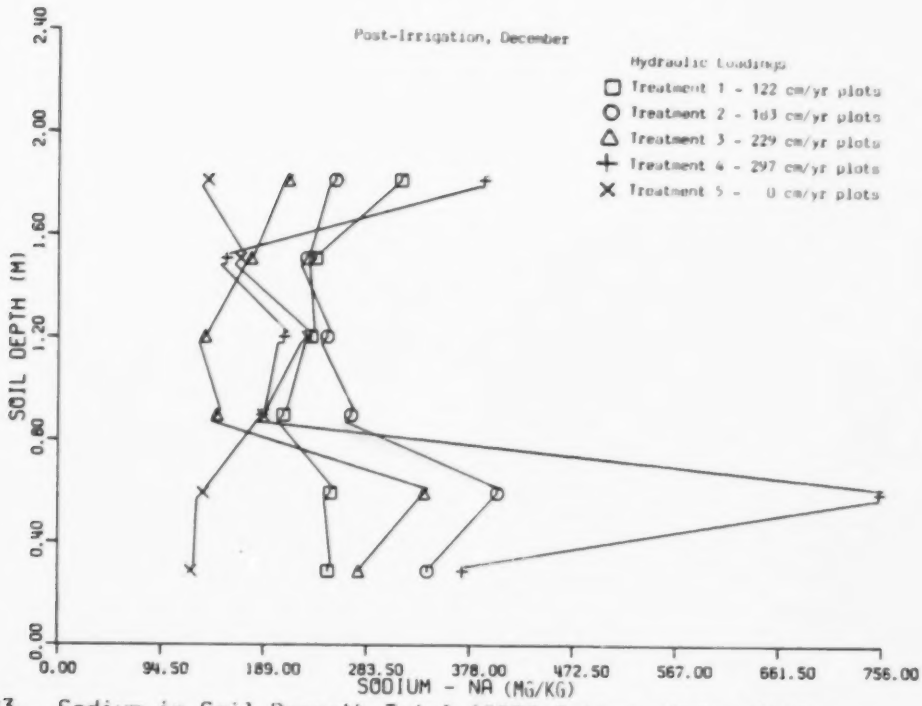


Figure 23. Sodium in Soil Beneath Trial 15000 Cotton plots, 1983

mass balance indicated the change in K between the winter 1983 and fall 1983 soil samples could not be accounted for by mass applied through irrigation and/or crop uptake. Spacial variability in conjunction with deep percolation of K contributed to the loss of K from the soil profile.

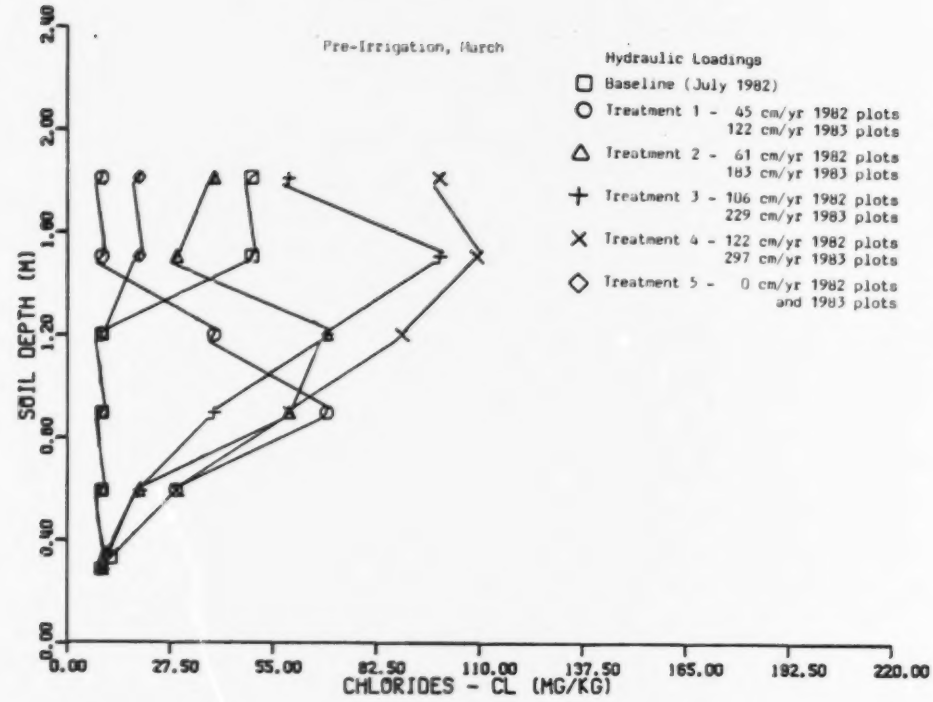
In general, as annual hydraulic loading increased the chloride concentration increased with increasing depth (Figures 24 and 25). In Trial 15000 the average chloride mass accumulated in the soil profile was 1080 kg/ha during the 1983 irrigation season. Assuming 183 cm of soil in Trial 14000 had equivalent chloride retention capacity, transport of chloride past 183 cm appeared to have occurred in test plots irrigated with 51 cm or more of effluent per year (Table E.26).

Sulfate (SO_4) exhibited a similar trend in the upper 122 cm as hydraulic loading varied from 122 cm/yr to 229 cm/yr (Figure 26). Soil obtained from the cotton plots receiving 297 cm/yr and the non-irrigated plots contained virtually the same sulfate concentration to a depth of 122 cm. At a depth of 152 cm, the SO_4 began to increase sharply to a level of 668 mg/kg.

Alfalfa

Crop Quality--

Municipal effluent hydraulic loadings to alfalfa test plots ranged from 23 to 137 cm in 1982 and 137 to 434 cm in 1983. Three freshwater control plots were established which received 76 to 137 cm in 1982 and 259 to 365 cm in 1983. Alfalfa yields for 1982 and in 1983 are presented in Table 12. The alfalfa harvest in May 1983 ranged from 2270 kg/ha (zero irrigation, Treatment 7) to 4340 kg/ha (Treatment 6). No significant difference ($\alpha = 0.05$) in May crop production was computed for any of the effluent irrigated crops. Furthermore, effluent irrigation of alfalfa in Treatments 3 (259 cm/yr), 4 (305 cm/yr) and 5 (365 cm/yr) did not generate significantly ($\alpha = 0.05$) greater quantities of alfalfa in May 1983 than the corresponding freshwater controls receiving similar hydraulic loadings, i.e., Treatments 12, 11 and 10, respectively. Alfalfa production obtained from effluent irrigated plots receiving more than 137 cm/yr was greatest in June 1983 (Figure 27). During the June harvest, the high-



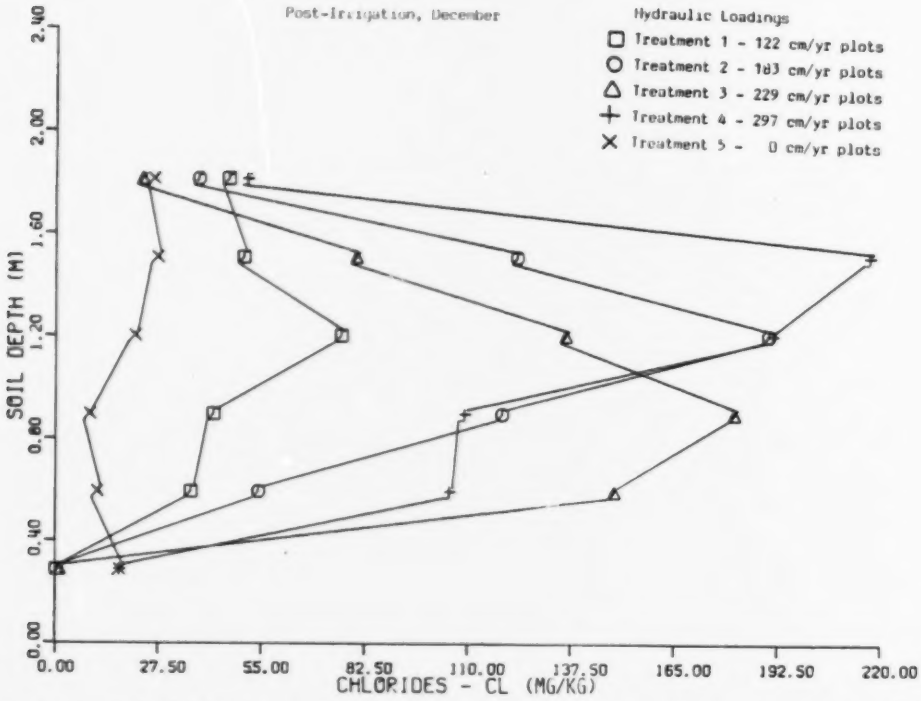
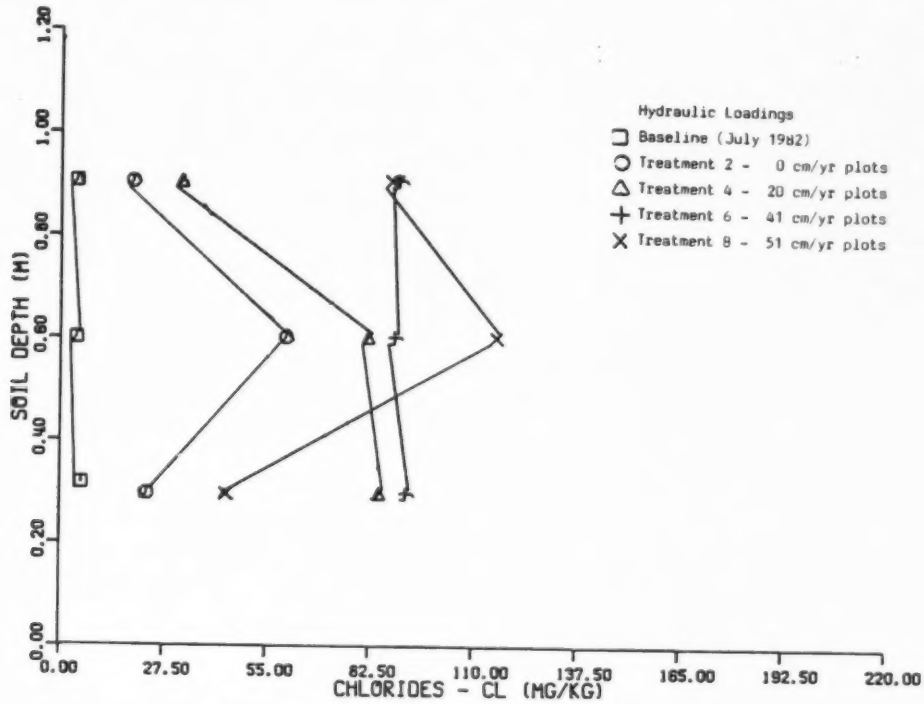


Figure 24. Chlorides in Soil Beneath Trial 15000 Cotton plots, 1983



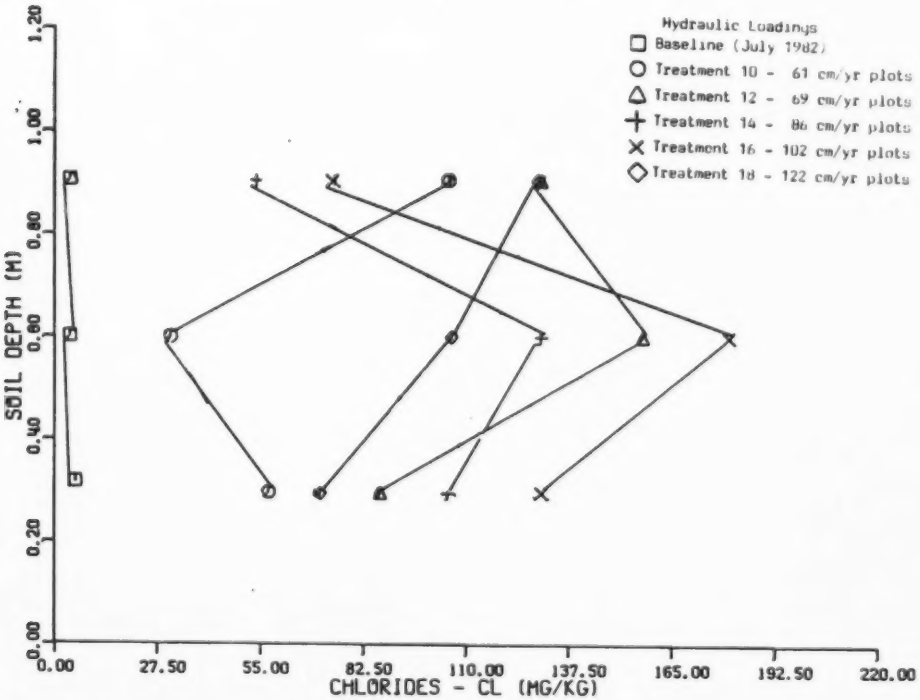


Figure 25. Chlorides in Soil Beneath Trial 14000 Cotton plots, Post-Irrigation December 1983

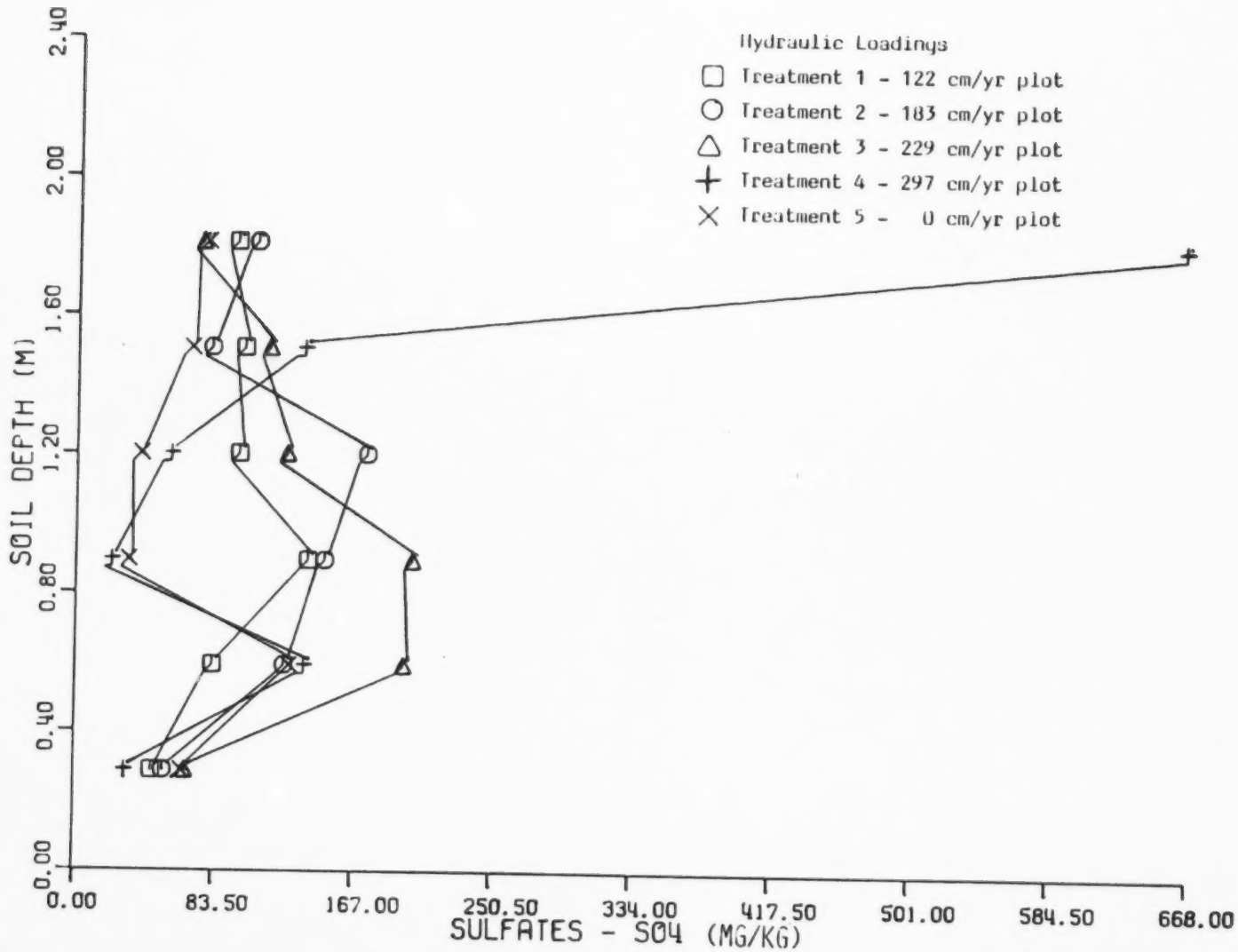


Figure 26. Sulfates in Soil Beneath Trial 15000 Cotton plots, Post-Irrigation, December 1983

TABLE 12. ALFALFA YIELD DATA, TRIAL 16000

Treatment	Annual Hydraulic Loading (cm) 1982	1983		Alfalfa Yield (kg/ha) Sept 1982	May 1983	June 1983	Aug 1983	Sept 1983	Nov 1983
1	23.	137.	Ave.		3520.	3390.	2830.	2550.	2380.
			SD		418.	497.	229.	382.	176.
2	46.	198.	Ave.		3820.	4740.	3380.	3120.	2260.
			SD		303.	657.	577.	598.	278.
3	76.	259.	Ave.		3610.	4620.	3550.	3630	2090.
			SD		934.	411.	502.	378.	256.
4	107.	305.	Ave.		3730.	4690.	3260.	3800.	2880.
			SD		939.	584.	314.	797.	527.
5	137.	365.	Ave.		3680.	5800.	4150.	4530.	2920.
			SD		767.	943.	441.	583.	661.
6	137.	434.	Ave.		4340.	5460.	3930.	4390.	3060.
			SD		1409.	278.	859.	299.	317.
7	0.	0.	Ave.		2450.	2210.	888.		1550.
			SD		561.	250.	104.		200.
*10	137.	365.	Ave.		2630.	2700.	2700.	1980.	2120.
			SD		594.	354.	219.	64.	247.
*11	107.	305.	Ave.		3500.	2700.	2240.	1820.	2020.
			SD		354.	354.	502.	220.	389.
*12	76.	259.	Ave.		2600.	2100.	1610.	2440.	1320.
			SD		912.	0.	14.	248.	212.

* Freshwater control plot
** Standard deviation

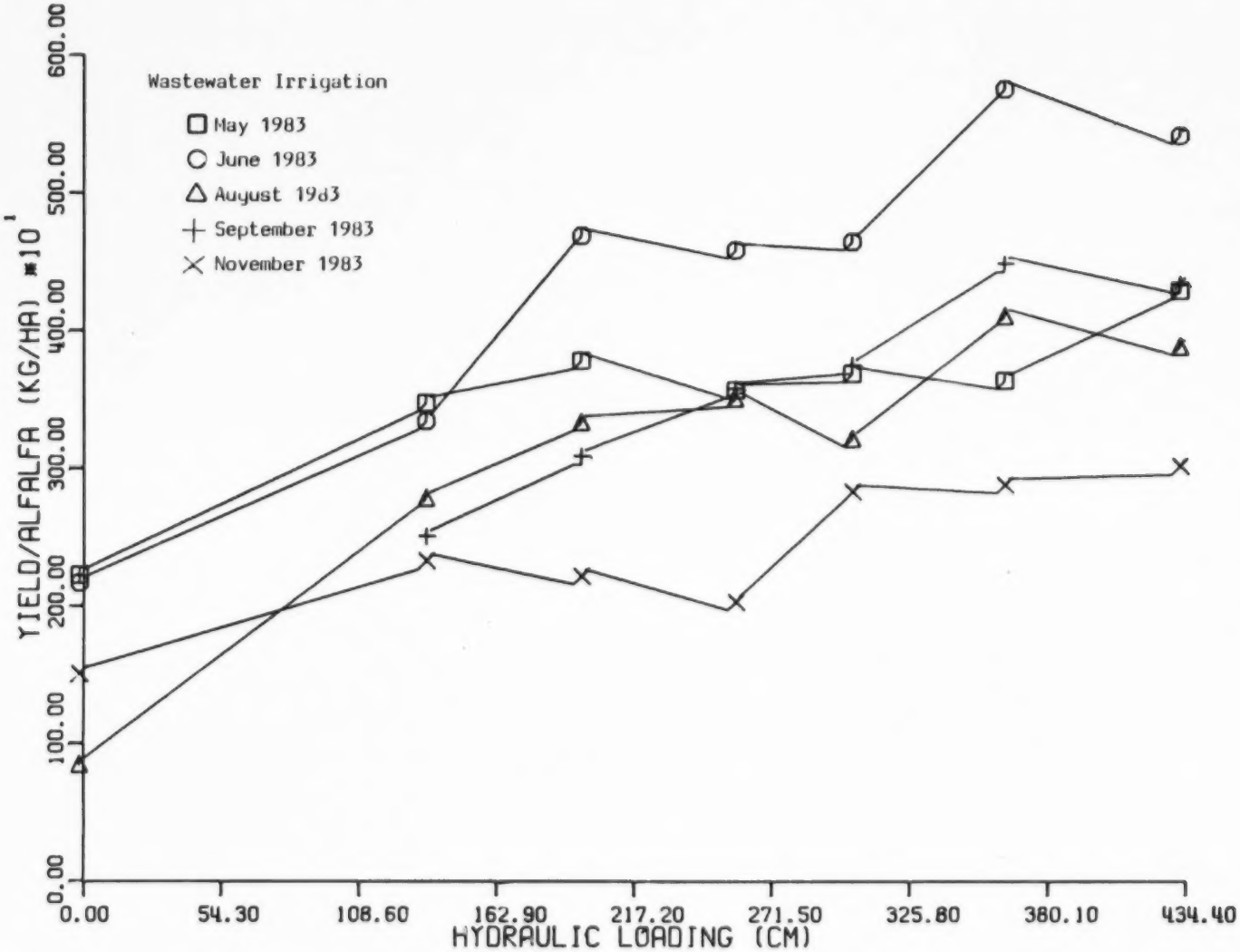


Figure 27. Crop Yield vs Hydraulic Loading in Trial 16000 Alfalfa plots

est average yield was produced from Treatment 5 (5800 kg/ha).

In general, Treatments 5 (365 cm/yr) and 6 (434 cm/yr) generated the highest yields during each cropping period. Statistically, no significant difference ($\alpha = 0.05$) in crop yields were computed between Treatments 5 and 6. Furthermore, crop yield harvested from Treatments 2, 3, and 4 were not significantly ($\alpha = 0.05$) different during 1983.

As shown in Figure 27, crop yields collected from effluent irrigated plots in May, August and September did not differ significantly ($\alpha = 0.05$). The lowest average yields were obtained in November.

Except for the May 1983 harvest, alfalfa plots receiving effluent annual hydraulic loadings of 259, 305 and 365 cm produced significantly ($\alpha = 0.05$) greater yields than alfalfa test plots irrigated with ground water at similar hydraulic loadings (Table 12). Greater quantities of alfalfa were harvested from Treatment 10 (365 cm of ground water/yr) in September (2705 kg/ha) and November (2125 kg/ha) than yields obtained from Treatment 12 (259 cm of ground water/yr) during the same cropping periods. Ground water irrigated alfalfa plots produced statistically ($\alpha = 0.05$) equivalent yields in May, June and September.

Table C.3 presents certain quality characteristics of the alfalfa crop harvested in September 1982 and 1983. In 1982, the percent protein contained in crops irrigated with municipal effluent ranged from 24 to 27 compared to 24 to 28 in 1983. The data indicated the crop tissue contained greater than 42 mg-N/g tissue (26 percent protein) once the wastewater irrigation equaled or exceeded 137 cm/yr up to 365 cm/yr. Protein in alfalfa normally ranges from 25 to 31 percent (Monson).

Phosphorus concentrations in the crop tissue were less than normal levels of 4 to 8 mg-P/g tissue. Crops harvested in September 1982 from effluent irrigated test plots contained 1.73 (Treatments 3 and 5) to 2.67 (Treatment 6) mg-P/g tissue (Table C.3). A slight increase in TP was measured in crop tissue in September 1983 and levels ranged from 2.12 (Treatment 2) to 2.84 (Treatment 6) mg-P/g tissue.

Ground water irrigated plots produced alfalfa having 1.85 to 2.08 mg-P/g in September 1982 and 1.43 to 1.57 mg-P/g in September 1983. Phosphorus in non-irrigated alfalfa tissue (1.65 and 1.43 mg-P/g tissue) was

less than effluent detected in ground water irrigated tissue. Low levels of phosphorus present in the crop tissue indicate possible phosphorus limitation to growth. Tissue nutrient ratios provided in Table C.8 indicate that phosphorus and potassium may have been unavailable to the crop.

Potassium levels in crop tissue harvested from effluent irrigated plots ranged from 21,900 to 26,000 ppm in September 1982 and 15,000 to 20,500 ppm in September 1983. All tissue potassium concentrations were below normal levels of 30,000 to 40,000 ppm. Therefore, phosphorus and potassium probably limited alfalfa growth and development during 1982 and 1983.

Soils--

Nitrogen--In 1983, total nitrogen uptake by alfalfa irrigated with 137 cm to 434 cm of municipal wastewater effluent per year ranged from 543 to 824 kg-N/ha (Table D.10). Maximum nitrogen removal from the soil solution by the crop occurred in test plots irrigated with 434 cm of effluent in 1983. Crop uptake of nitrogen exceeded normal anticipated values of 225 to 540 kg-N/ha.yr (EPA 1981, A & L Soil and Plant Tissue Analysis Handbook). The concentration of nitrogen in the plant tissue collected in September 1982 was approximately the same as levels measured in September 1983. In September 1982, low nitrogen removal from the soil was a result of the poor yields.

As noted previously, organic nitrogen was the dominate nitrogen form present in the soil profile. Organic N comprised 99 percent of the TKN. After the 1982 irrigation season, the concentration of TKN in the upper 61 cm of soil of the irrigated plots was greater than the concentration measured prior to irrigation (Figure 28). Maximum organic N concentrations existed in the second 30 cm from the soil surface. TKN levels decreased rapidly with increasing depth to 152 cm. In 1983, virtually no difference was observed in organic N concentration measured in soils collected from ground water irrigated plots, wastewater irrigated plots (>137 cm/yr), and non-irrigated plots (Figure 29). The majority of the organic N in the upper 61 cm probably consisted of roots and associated biomass. Analysis of baseline soil samples collected July 1982 indicated a NO_2 +

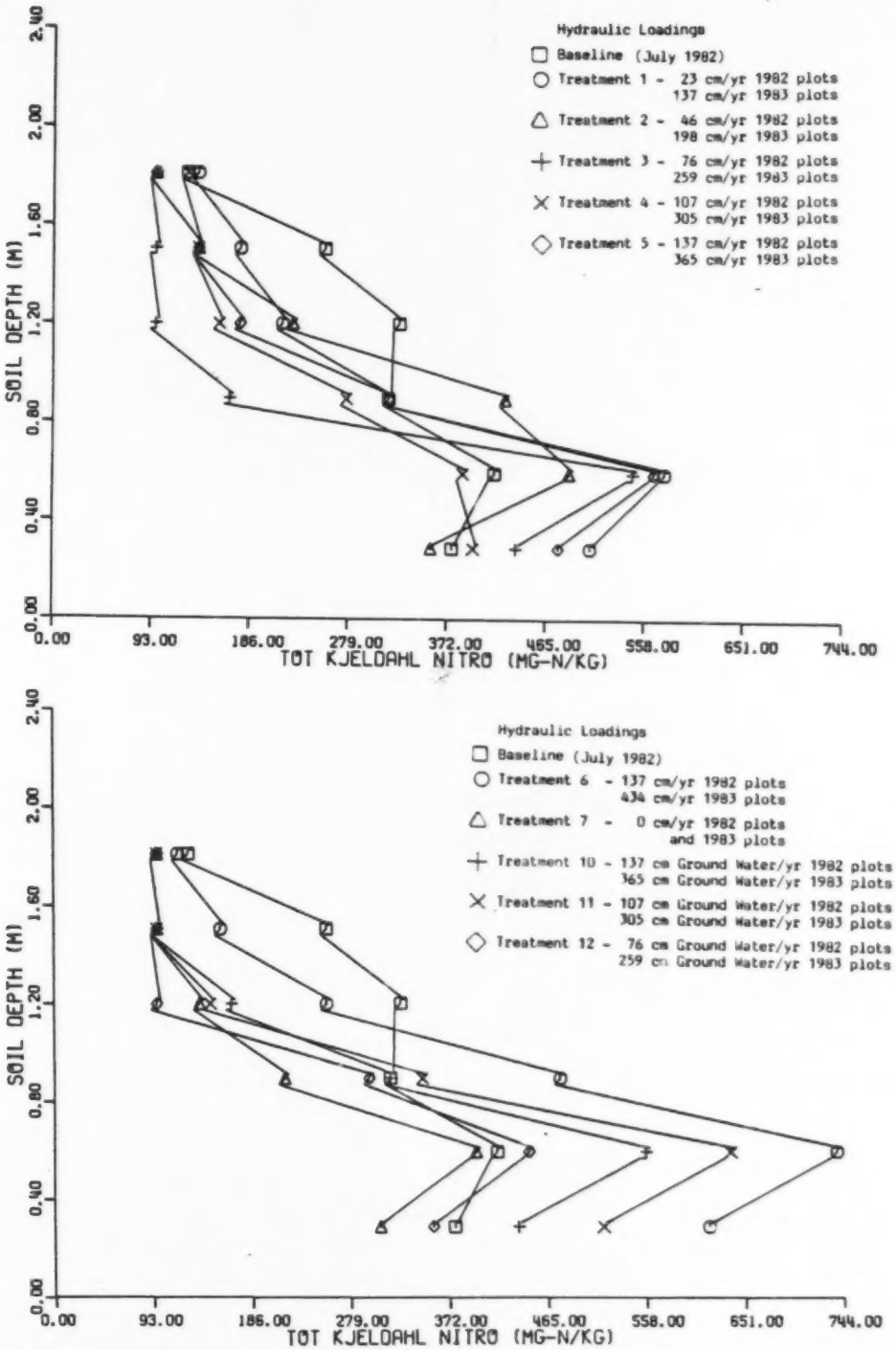
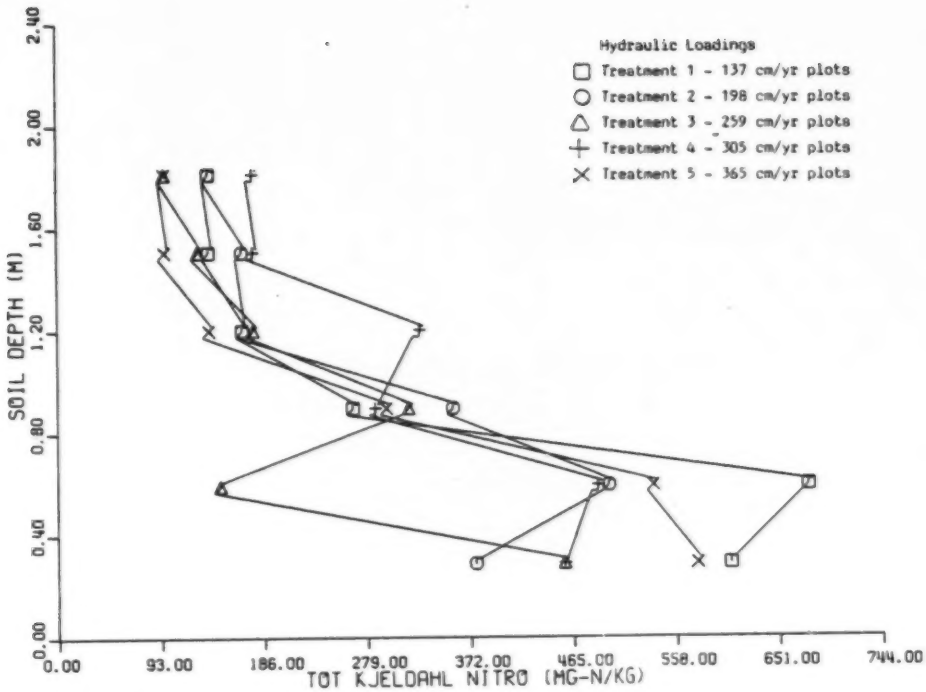


Figure 28. Total Kjeldahl Nitrogen in Soil Beneath Trial 16000 Alfalfa plots, Pre-Irrigation, March 1983



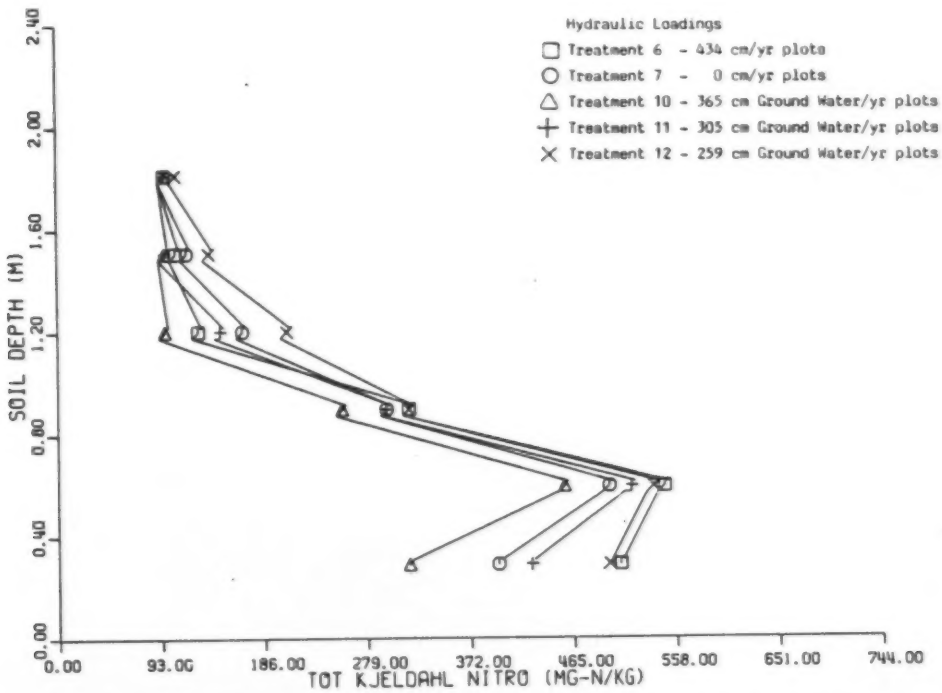


Figure 29. Total Kjeldahl Nitrogen in Soil Beneath Trial 16000 Alfalfa plots Post-Irrigation, December 1983

NO_3-N lens to exist between 122 cm and 183 cm within the soil profile (Figure 30). After the 1982 irrigation period, NO_2 + NO_3-N exhibited an increase from approximately 7 mg-N/kg to 19.2 mg-N/kg at 183 cm depth (Figure 30). Whereas, NO_2 + NO_3-N apparently accumulated in the upper 91 cm of Treatment 3 (76 cm/yr). Nitrate nitrogen was removed from the lower 91 cm of the 183 cm core in test plots receiving an annual hydraulic loading of 137 cm (Treatments 5 and 6)(Figure 30). Soils collected from ground water irrigated plots (76 cm/yr to 137 cm/yr) also contained very little NO_2 + NO_3-N (<1.0 ppm)(Figure 30). In 1983 no differences were observed between various annual hydraulic loadings or water source and NO_2 + NO_3-N levels in the soil profile (Figure 31). NO_2 + NO_3 were quite uniform throughout the soil profile and generally less than 1 ppm.

A nitrogen mass balance was conducted on each of the Treatments. Table D.3 provides the initial conditions and assumptions incorporated into the mass balance. The nitrogen mass balance (Figure 32) indicated that the alfalfa utilized all the inorganic nitrogen entering or produced within the 183 cm soil profile. In addition, the crop had to fix nitrogen to satisfy its nitrogen requirement. Consequently, no nitrogen apparently was transported beyond 183 cm depth in any alfalfa test plot.

Phosphorus--As alfalfa received larger phosphorus mass loadings, greater quantities of phosphorus were removed from the soil solution by the crop (Table E.31). Spacial variability in the phosphorus levels within Treatment 1 accounted for the tremendous increase in total phosphorus (TP) levels during 1983. In general, TP was fairly uniform throughout the entire 183 cm soil profile and appeared to decrease during the 1983 growing season. A portion of the dissolved phosphorus present in the soil solution may have been leached beyond the 183 cm depth (Table E.3). Phosphorus uptake by alfalfa irrigated with effluent was within the normal range of 22 to 35 kg-P/ha.yr (EPA 1981). Alfalfa irrigated with ground water utilized 14.03, 16.70, and 18.61 kg-P/ha.yr compared to 38.53, 44.01, and 51.00 kg-/ha.yr removed by alfalfa irrigated with municipal effluent at similar annual hydraulic loadings of 259, 305 and 365 cm, respectively. Sorption processes made most of the inorganic phosphorus

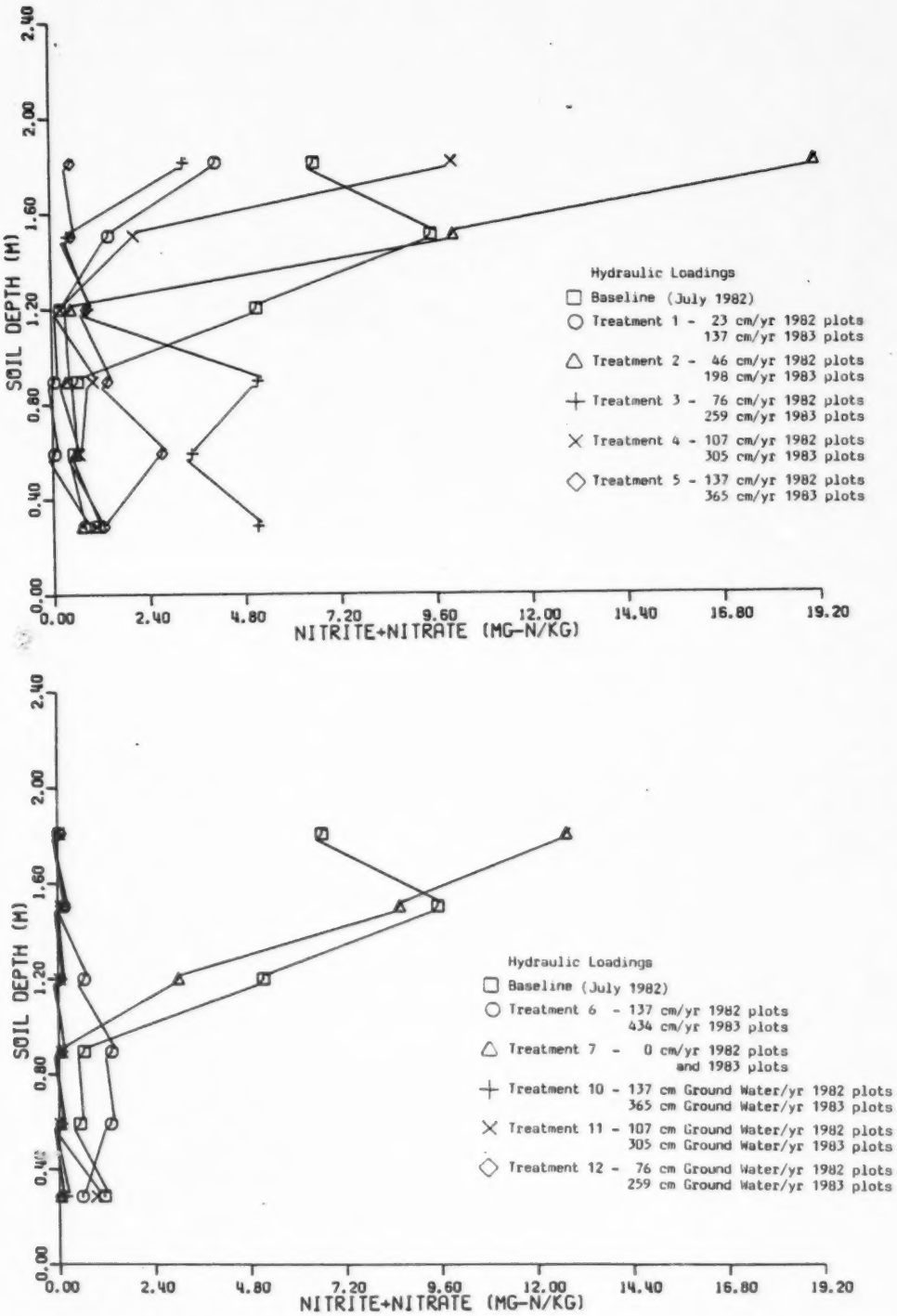
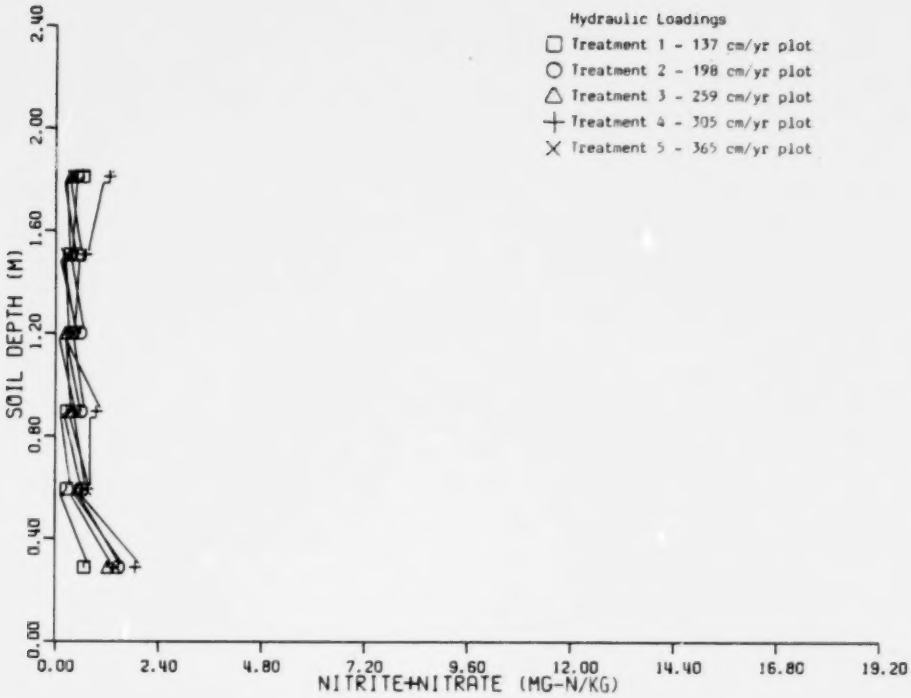


Figure 30. Nitrite plus Nitrate in Soil Beneath Trial 16000 Alfalfa plots, Pre-Irrigation, March 1983



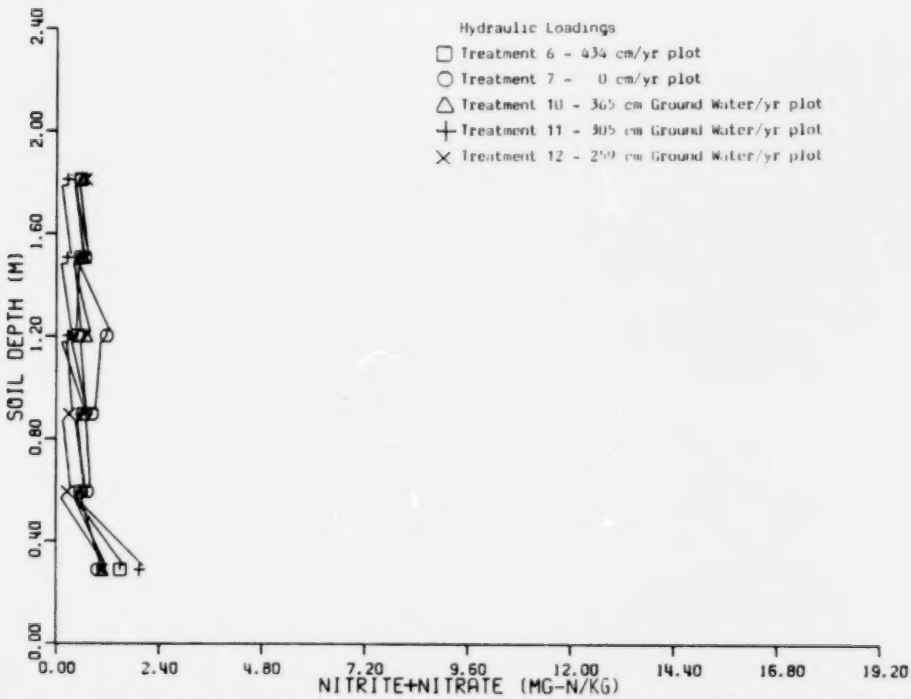


Figure 31. Nitrite plus Nitrate in Soil Beneath Trial 16000 Alfalfa plots, Post-Irrigation, December 1983

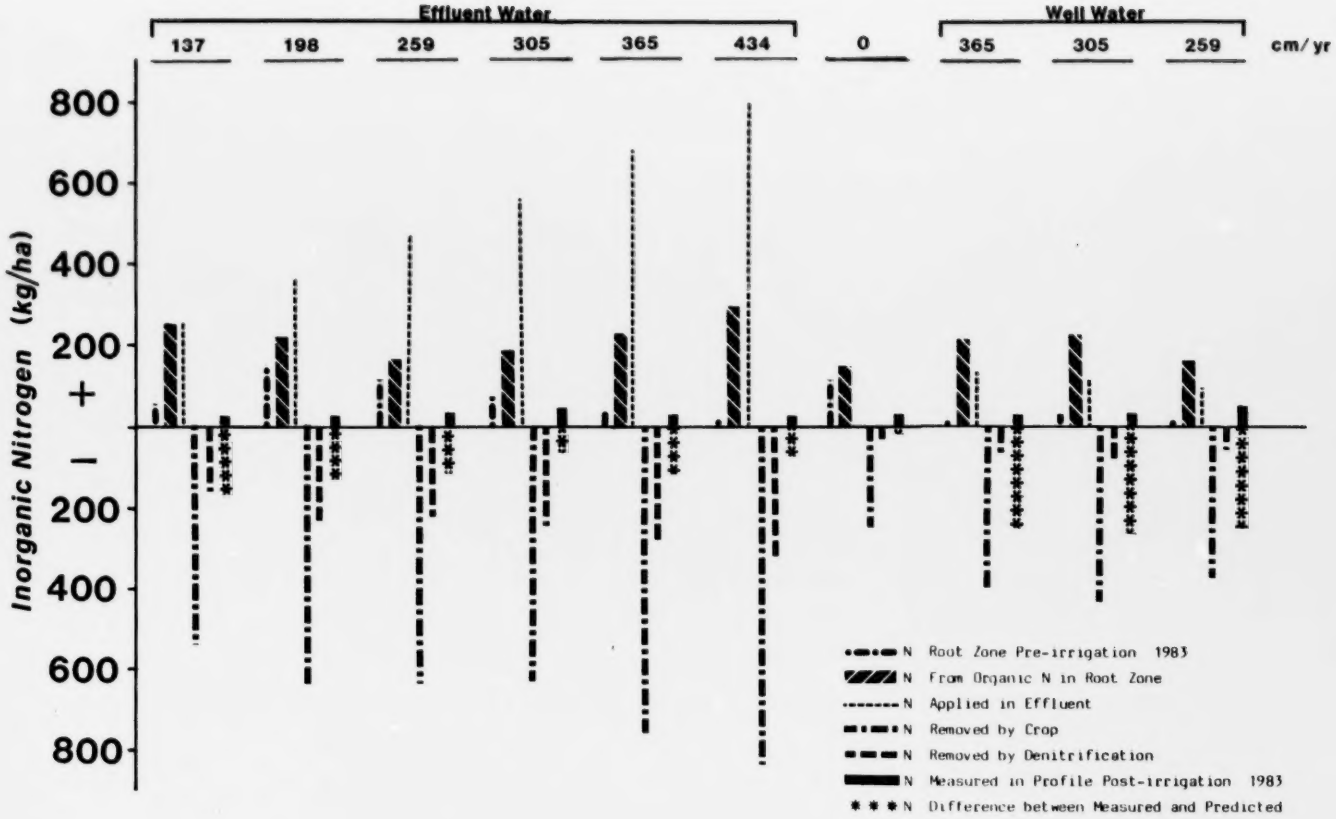


Figure 32. Nitrogen Mass Balance for Trial 16000 Alfalfa

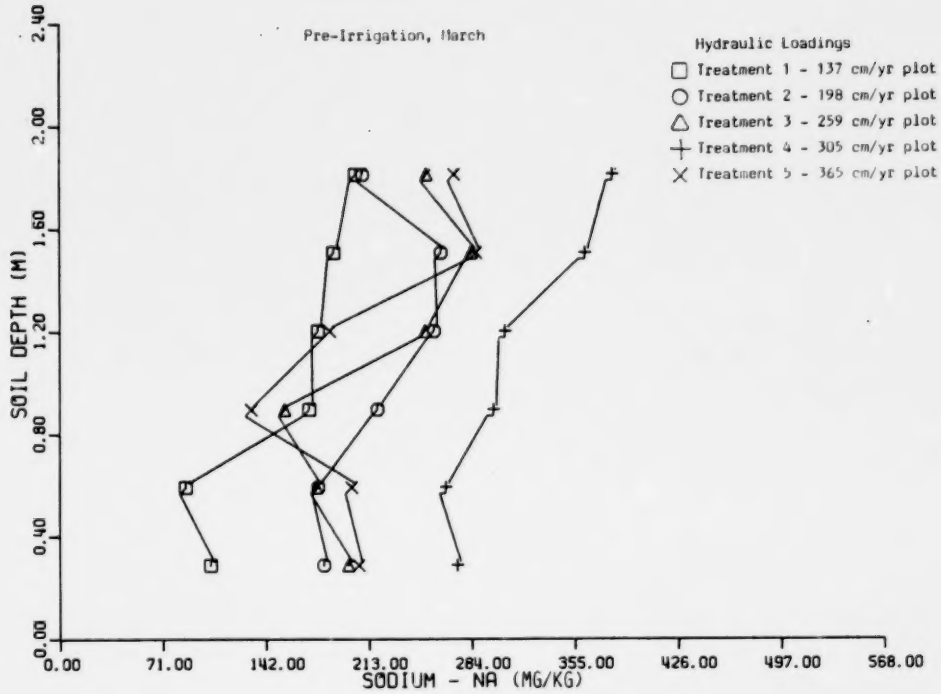
unavailable to the crop.

Dissolved Solids--During the 1983 irrigation season total dissolved solids (TDS) accumulated within the soil's profile of alfalfa test plots irrigated with effluent (Figures E.3 and E.4). Test plots irrigated with ground water exhibited a decrease in TDS primarily in the lower 91 cm of the 183 cm soil core. During 1983 all irrigated test plots leached TDS below a depth of 183 cm (Table E.9).

The primary cause for the increase in TDS in the soil profile of Treatments 3, 4, and 5 compared to the relatively small TDS decrease in Treatments 10, 11, and 12, which received the same hydraulic loadings, was the higher average level of Na present in the effluent (307 ppm) than existed in the ground water (105 ppm). The adjusted Na adsorption ratio (SAR_{adj})(Table F.1) was 17.8 for the municipal effluent and 6.0 for the ground-water source; consequently, there was a greater potential for adsorption of Na in the soil irrigated with effluent. During 1983, Na was accumulated in the upper 61 cm of soil in each treatment receiving municipal effluent (Figures 33 and 34). Annual effluent loadings from 198 cm to 305 cm produced sodium increases in the soil extending to a depth of 122 cm. Soils collected from alfalfa plots receiving 434 cm of effluent per year demonstrated an increase in Na concentration at the 61 cm depth in 1983 (Figure 34). Sodium mass balance indicated Na salts were leached below 183 cm depth (Table E.15). An average of 3238 $\pm$ 558 kg-Na/ha was accumulated in the upper 183 cm of soil within test plots irrigated with 137 cm to 365 cm of municipal effluent per year.

The upper 61 cm of soil extracted from alfalfa test plots irrigated with effluent exhibited an increase in ESP from a range of 0.9 to 4.6 (February 1983) to 4.0 to 9.6 (December 1983, Table F.4). Fresh water control plots only experienced a slight increase in ESP (0.9 percent) within the top 30 cm of soil.

Leaching of salts controlled the ESP within the profile and inhibited the development of sodic conditions (ESP $\geq$ 15). Except for alfalfa produced in Treatment 1 (137 cm/yr), more K was applied to the land in each treatment than was utilized by the crop (Table E.32). In the effluent



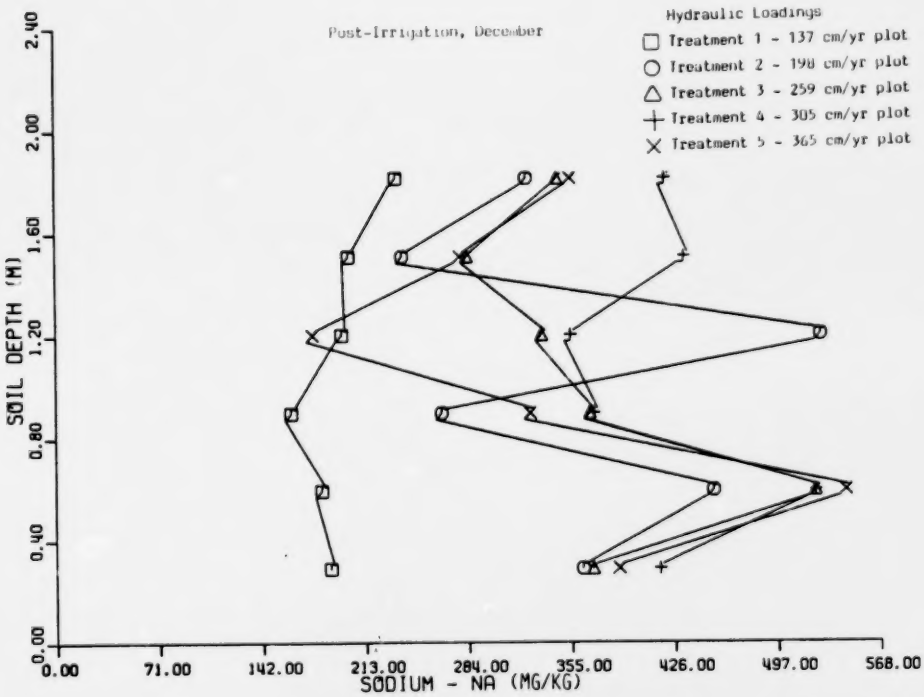
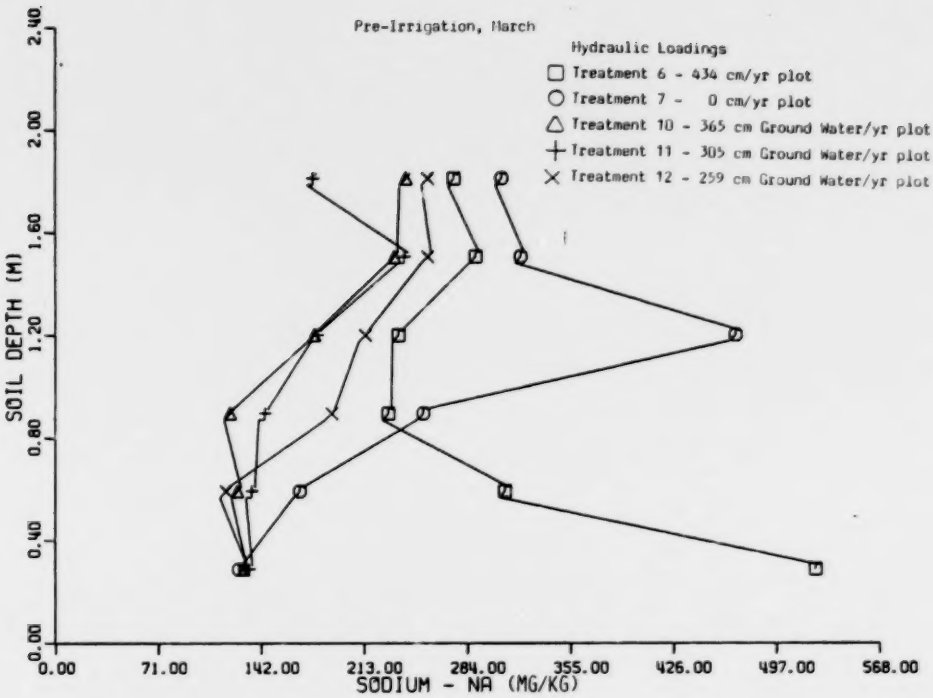


Figure 33. Sodium in Soil Beneath Trial 16000 Alfalfa plots, 1983



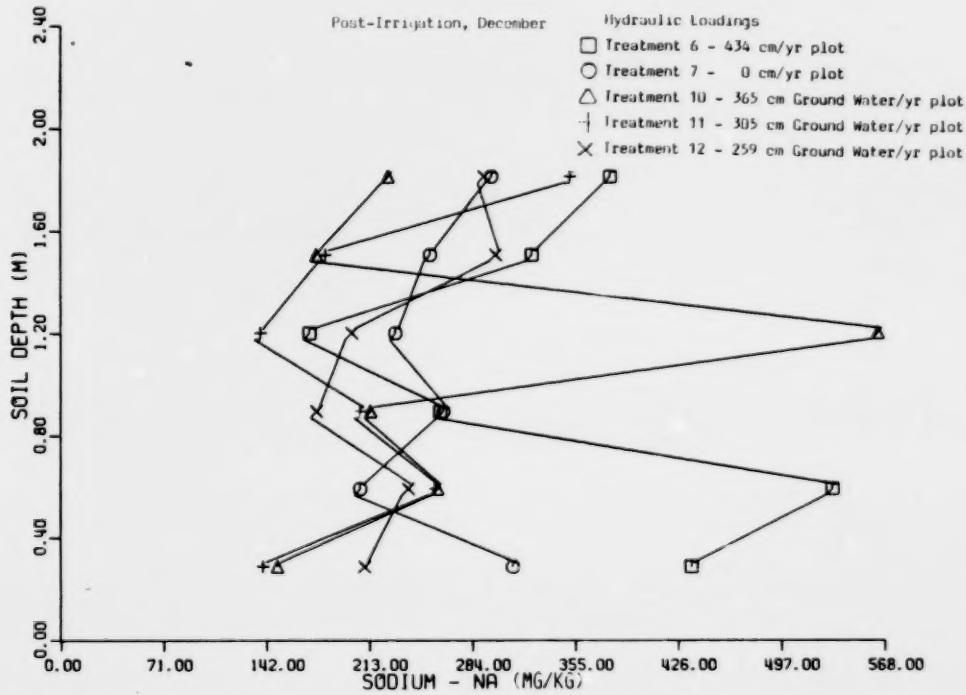


Figure 34. Sodium in Soil Beneath Trial 16000 Alfalfa plots, 1983

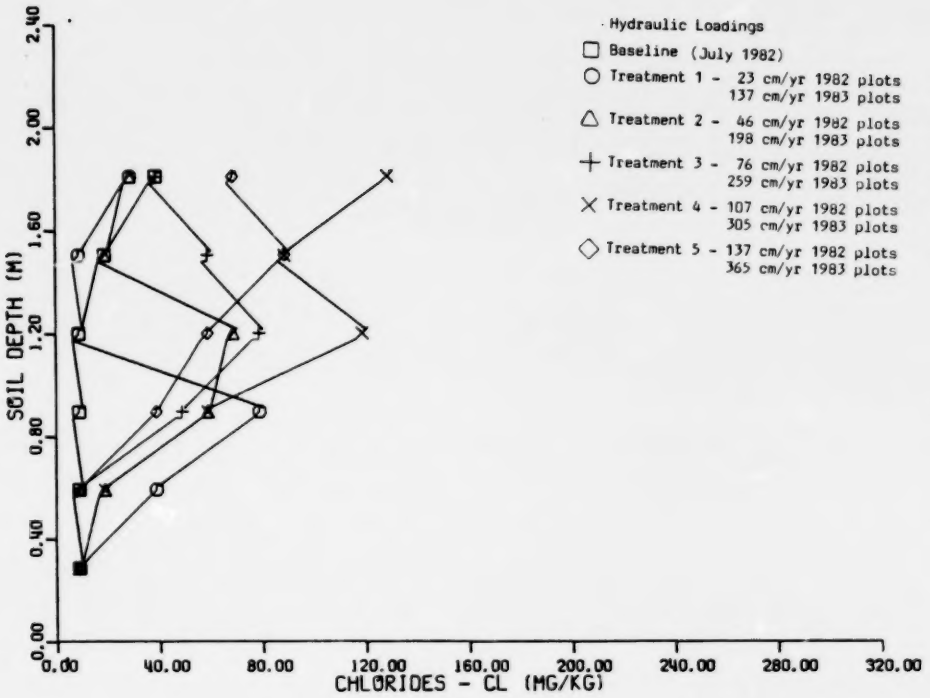
treated plots, maximum K removed by crops (492 kg/ha.yr) was obtained in Treatment 5 which received 365 cm of irrigation. Crop uptake of K in 1983 was only 251 kg/ha.yr. The K mass applied to the test plots; however, was 307 kg/ha.yr due to the lower average potassium level (19.5 mg/l) in the ground water.

Chloride ion accumulated in the soil profile from 61 cm to 183 cm/yr in effluent treated plots receiving 137 to 365 cm/yr (Figures 35 and 36). An average of 2325 $\pm$ 582 kg Cl/ha was stored in the 183 cm profile. Increases in chloride levels at the 61 cm and 91 cm depth was detected in Treatment 6 (431 cm/yr). Chloride accumulation amounted to only 969 kg/ha. Due to the low chloride mass loading to ground-water treated plots (1968 to 2774 kg/ha), virtually no difference was measured in Cl levels in the soil profile within these plots.

Common Bermuda Grass

The bermuda grass harvested in 1982 was affected by the severe weather conditions which existed in May and June 1982 (approximately 38 cm of precipitaiton and hail damage). During 1982 and 1983, effluent irrigated bermuda plots produced more crop mass than the non-irrigated plot (Table 13). Furthermore, in September 1983 the yield obtained from each irrigated plot exceeded the yield harvested the previous September. The increased crop production was probably a function of increased irrigation and climatic conditions. During June and September, 1983, the highest bermuda yield (9368 $\pm$ 2327 kg/ha) was collected from the lowest annual effluent hydraulic loading of 152 cm. As the quantity of applied effluent per year increased above 152 cm in 1983, no statistically significant (α = 0.05) differences could be computed between corresponding crop yields.

Chemical analysis of the crop tissue harvested in September 1982 and 1983 is presented in Table C-4. Less nitrogen existed in the irrigated crop tissue in September 1983 (9.67 to 13.1 mg-N/g tissue) than in tissue collected in September 1982 (17.2 to 20.6 mg-N/g). In 1983, tissue collected from Treatments 11 (11.95 mg-N/g), 2 (12.03 mg-N/g), 4 (11.76 mg-N/g), 5 (9.67 mg-N/g), and 6 (10.20 mg-N/g) contained less nitrogen than bermuda tissue obtained from the non-irrigated plot (13.09 mg-N/g).



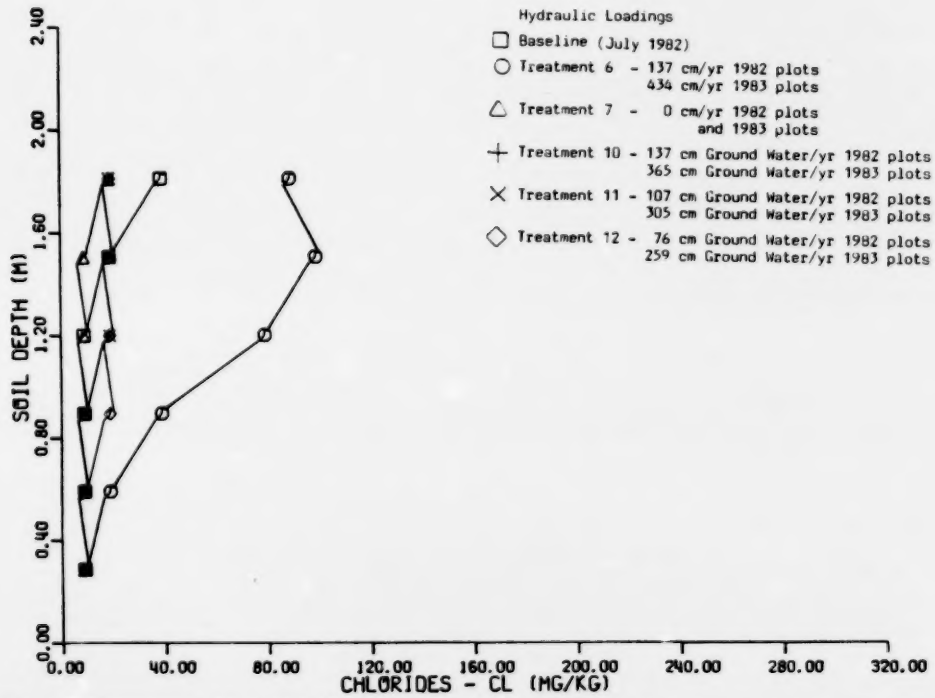


Figure 35. Chlorides in Soil Beneath Trial 16000 Alfalfa plots, Pre-Irrigation March 1983

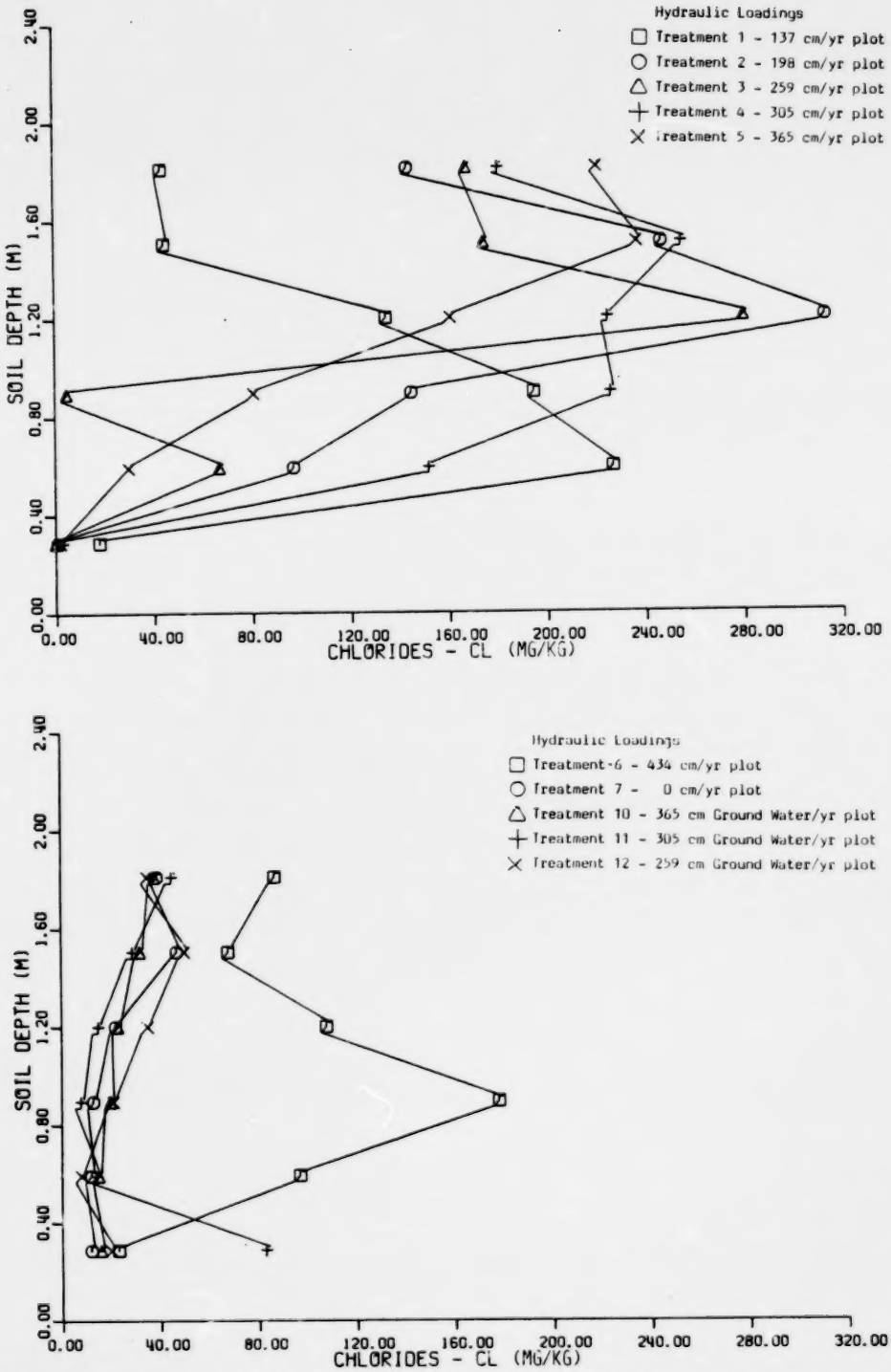


Figure 36. Chlorides in Soil Beneath Trial 16000 Alfalfa plots, Post-Irrigation, December 1983

TABLE 13. BERMUDA YIELDS OBTAINED FROM TEST PLOTS IN TRIAL 16000

Treatment	Annual Hydraulic Loading (cm) 1982	1983		Bermuda Crop Yields (kg/ha) September 1982	June 1983	September 1983
1	38.	152.	Ave.	*(1) 3970.	*(2) 5110.	*(4) 9370.
			S.D.	972.	2330.	
2	46.	198.	Ave.	*(1) 4970.	*(2) 4140.	*(4) 8170.
			S.D.	1290.	1220.	
3	76.	259.	Ave.	*(1) 3520.	*(2) 4650.	*(4) 6450.
			S.D.		424.	1070.
4	91.	305.	Ave.	*(1) 4490.	*(2) 4520.	*(4) 7260.
			S.D.		1308.	563.
5	122.	350.	Ave.	*(1) 5490.	*(2) 3880.	*(4) 6470.
			S.D.		247.	951.
6	152.	396.	Ave.	*(1) 4300.	*(2) 4650.	*(4) 7090.
			S.D.		212.	1350.
7	0.	0.	Ave.	*(1) 2300.	*(2) 3350.	*(4) 2930.
			S.D.		283.	841.

Ave = Average
S.D. = Standard Deviation
* = Number Sampled

Higher nitrogen levels were present in tissue samples harvested from wastewater irrigated plots compared to the nitrogen concentration in non-irrigated bermuda in September 1982. Nitrogen levels measured within the bermuda were all below normal levels of 25.0 to 35.0 mg-N/g tissue (Monson 1978). With the shallow root system of bermuda, increased irrigation may have leached nitrogen past the root zone; thereby, limiting the quantity of nitrogen available to the crop.

Similarly, the availability of phosphorus to the crop may have been limited. Average phosphorus levels in crop tissue obtained from effluent irrigated plots were 1.89 $\pm$ 0.78 mg-P/g tissue in 1982 and 1.46 $\pm$ 0.15 mg-P/g in 1983. Non-irrigated bermuda contained 0.60 mg-P/g and 0.77 mg-P/g in 1982 and 1983, respectively. Phosphorus content of every bermuda sample was below the normal concentration ranges of 3 to 4 mg-P/g.

In addition, available zinc deficiencies in the soil may have inhibited growth of the bermuda. This zinc deficiency was reflected in the lower zinc concentrations in the tissue samples (14.2 to 17.9 mg/kg). Normal zinc levels in coastal bermuda are 25 to 40 mg/kg (Monson 1978). The alkaline, calcareous soils existing in the test plot most likely increased the occurrence of zinc deficiencies.

Nutrients such as potassium, iron, manganese, and calcium in crop tissue produced with effluent irrigation were at higher levels in 1982 than 1983 (Table C.4). In 1983 harvested bermuda from effluent irrigated plots contained K (15,850. $\pm$ 1773 mg/kg) and Fe (134. $\pm$ 25 mg/kg) at levels less than normal ranges (K: 20,000 to 30,000 ppm and Fe: 200 to 400 ppm). The nutrient deficiencies may have resulted from the heavy flood irrigation of the bermuda.

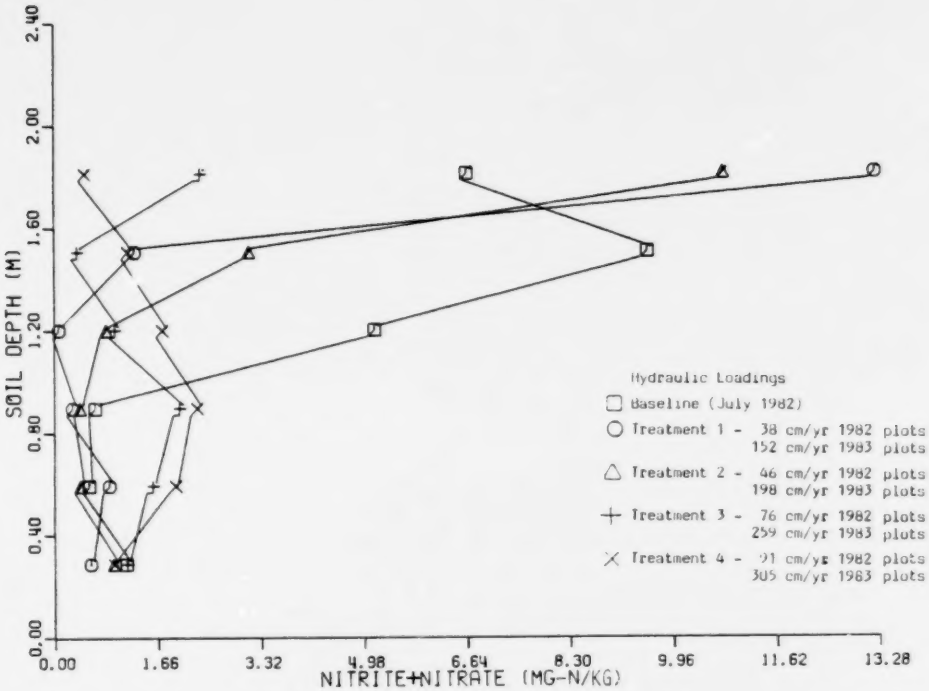
Periodic saturation of the soil within the upper 30 cm of the profile during irrigation events may have created anaerobic conditions which could have caused reduction of iron from an oxidation state of III to II and similarly, manganese (Mn) could have been reduced from Mn(IV) to Mn(II). Both ions in their respective reduced oxidation states are quite soluble. With the shallow root system of bermuda, Fe(II), Mn(II), inorganic N and inorganic P may not have been available to the crop due to transport of these constituents past the root zone by percolate water.

Soils--

Nitrogen--Organic nitrogen was the major nitrogen form present in the soil profile of the bermuda plots (Table D.11. Less than one percent of the total N present in the 183 cm soil profile in February and December 1983 was NH_3-N or NO_2 + NO_3-N. Primarily, the organic-N concentration existed in the upper 61 cm of soil. Accumulation of nitrate salts within the soils profile of Treatments 7 and baseline soil cores appeared to have existed at depths between 122 and 183 cm (Figure 37). Due to severe weather conditions, less effluent was applied to the test plots in 1982 than 1983. In 1982, increases in NO_2 + NO_3-N concentrations occurred at the 61 cm and 91 cm soil depth within Treatments 3 (76 cm/yr), 4 (91 cm/yr), and 5 (122 cm/yr)(Figure 37). Soils collected from test plots irrigated with 152 cm of effluent in 1982 did not accumulate NO_2 + NO_3-N. In December 1983, a very uniform NO_2 + NO_3-N profile existed within all effluent irrigated plots (Figure 38).

A nitrogen mass balance was conducted on each test plot. Initial conditions for the solution of equation 3 are provided in Table D.4. The quantity of nitrogen removed from the soil-water matrix by bermuda is presented in Table D.12. These nitrogen uptake rates are below cited rates of 400 to 675 kg/ha.yr for coastal bermuda grass (EPA, 1981). Based on the assumptions made in the computation of the nitrogen mass balance, the predicted inorganic nitrogen mass within the 183 cm soil profile of each test plot exceeded actual measured mass levels (Figure 39). The low inorganic nitrogen concentrations (<1 ppm) throughout the entire 183 cm soil profile in each test plot and the results of the mass balance indicate deep percolation of inorganic nitrogen was an important mechanism for removal of nitrogen from the 183 cm soil core in all treatments. The shallow root system of the bermuda crop limited the crops ability to extract nitrogen and other nutrients being transported through the soil profile below the root zone. The mass balance mode adequately defines the dominate mechanisms governing the transformation and removal nitrogen within the non-irrigated plot (Treatment 7).

Phosphorus--As previously indicated, the bermuda may have suffered



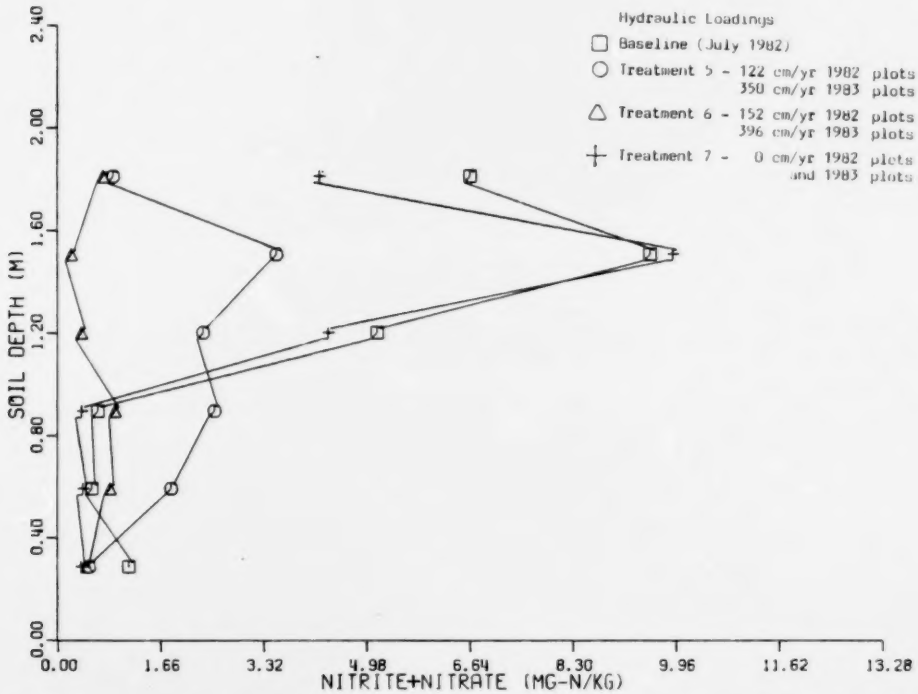


Figure 37. Nitrite plus Nitrate in Soil Beneath Trial 16000 Bermuda plots, Pre-Irrigation, March 1983

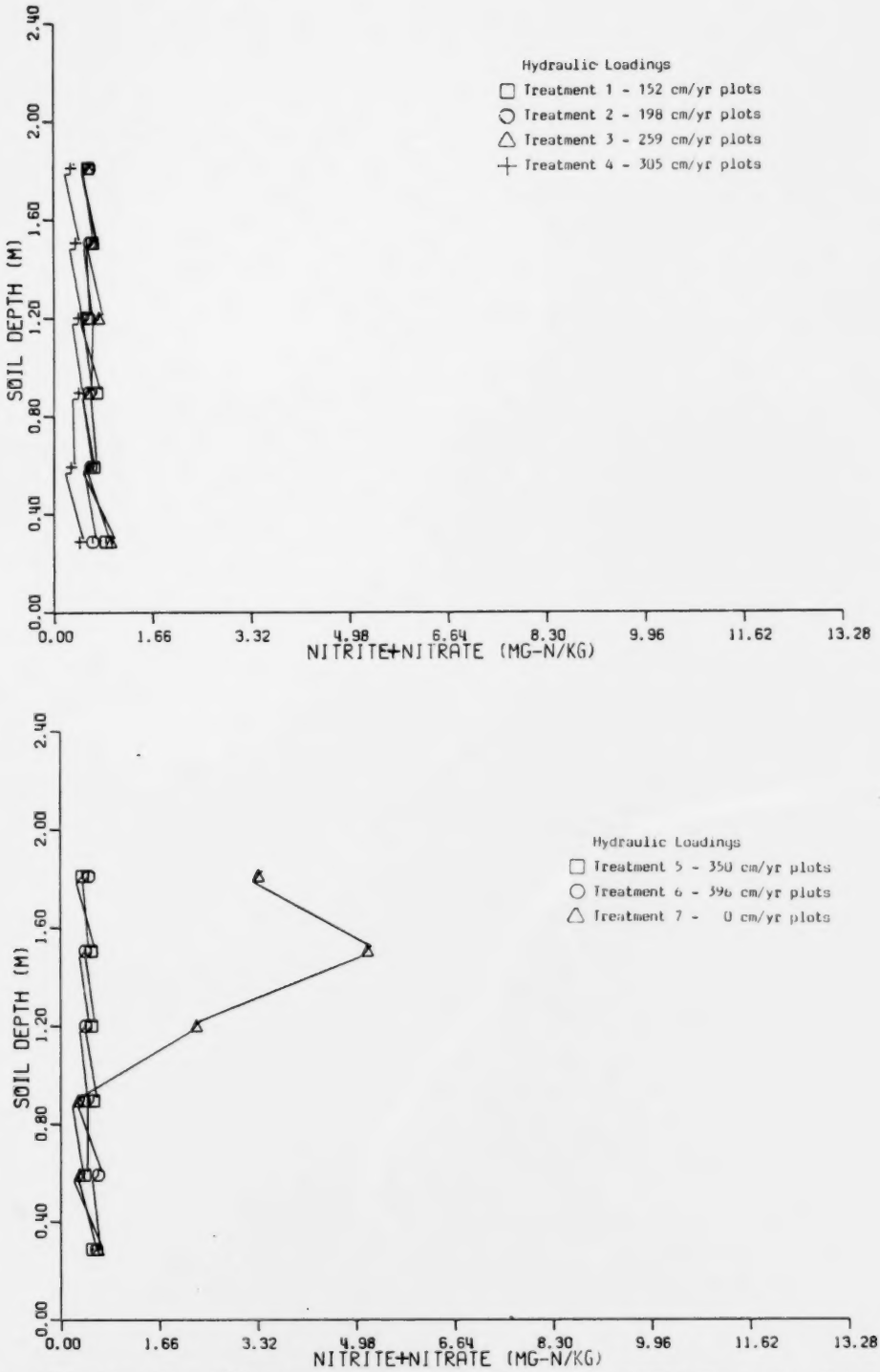


Figure 38. Nitrite plus Nitrate in Soil Beneath Trial 16000 Bermuda, Post-Irrigation, December 1983

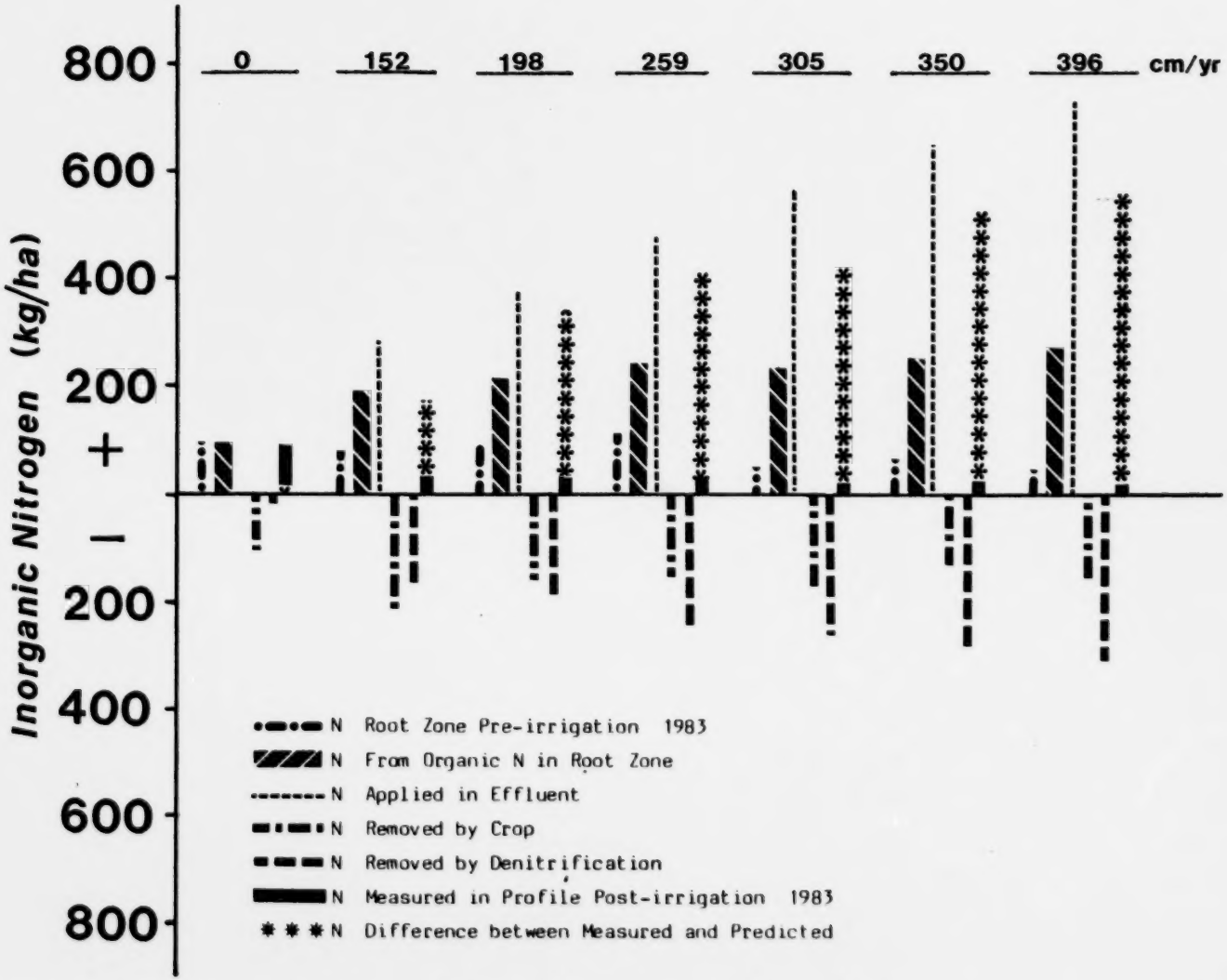


Figure 39. Nitrogen Mass Balance for Trial 16000 Bermuda Grass Plots

from phosphorus deficiency. Table E.33 presents the quantity of phosphorus removed by harvested bermuda. An average of 18.4 $\pm$ 1.1 kg-P/ha.yr was removed from the test plots by means of cropping the bermuda. This crop uptake rate was below normal ranges of 35 to 45 kg-P/ha.yr (EPA, 1981). Phosphorus utilized by the crop was not a function of phosphorus mass loading and was only 6 to 17 percent of the applied phosphorus mass (Table E.4). The amount unaccounted for phosphorus mass implies that dissolved phosphorus was possibly leached past the 183 cm soil profile within each plot. Dissolved phosphorus, which is available to the crop, however, comprises only a small portion of the total phosphorus. Flood irrigation and subsequent leaching of nutrients past the shallow root zone of bermuda probably limited the availability of macro and micro nutrients to the crop.

Dissolved Solids--Dissolved solids were leached through the soil profile within all treated bermuda plots (Table E.10). Greater than 80 percent of the TDS mass applied through irrigation was transported through 183 cm of soil. The non-irrigated control plot contained approximately the same TDS mass in February (10,400 kg/ha) and December (10,700 kg/ha) 1983. Increasing TDS concentrations within soil depth were measured as TDS mass loadings increased (Figure E.5) up to 37,500 kg TDS/ha.yr (Treatment 4). With higher mass loadings a larger fraction of the applied TDS mass was leached through the soil. Associated with the deep percolation of salts was the leaching of Na ion. From 67 to 94 percent of the Na applied through effluent irrigation was leached through 183 cm of soil.

During the 1983 irrigation season, Na primarily accumulated within the top 61 cm of all irrigated plots (Figures 40 and 41). In Treatment 5, the Na lense was translocated from the 91 cm depth to the 152 cm soil depth. Table F.5 presents the exchangeable Na percentage (ESP) as computed from a calculated cation exchange capacity for each soil depth. The increase in Na within the upper 61 cm of soil resulted in an increase in the ESP. Prior to irrigation in 1983, the ESP on the top 30 cm of soil ranged from 1.8 (Treatment 1) to 6.2 (Treatment 6). This rise in Na levels was a result of limited effluent irrigation in 1982; high Na mass

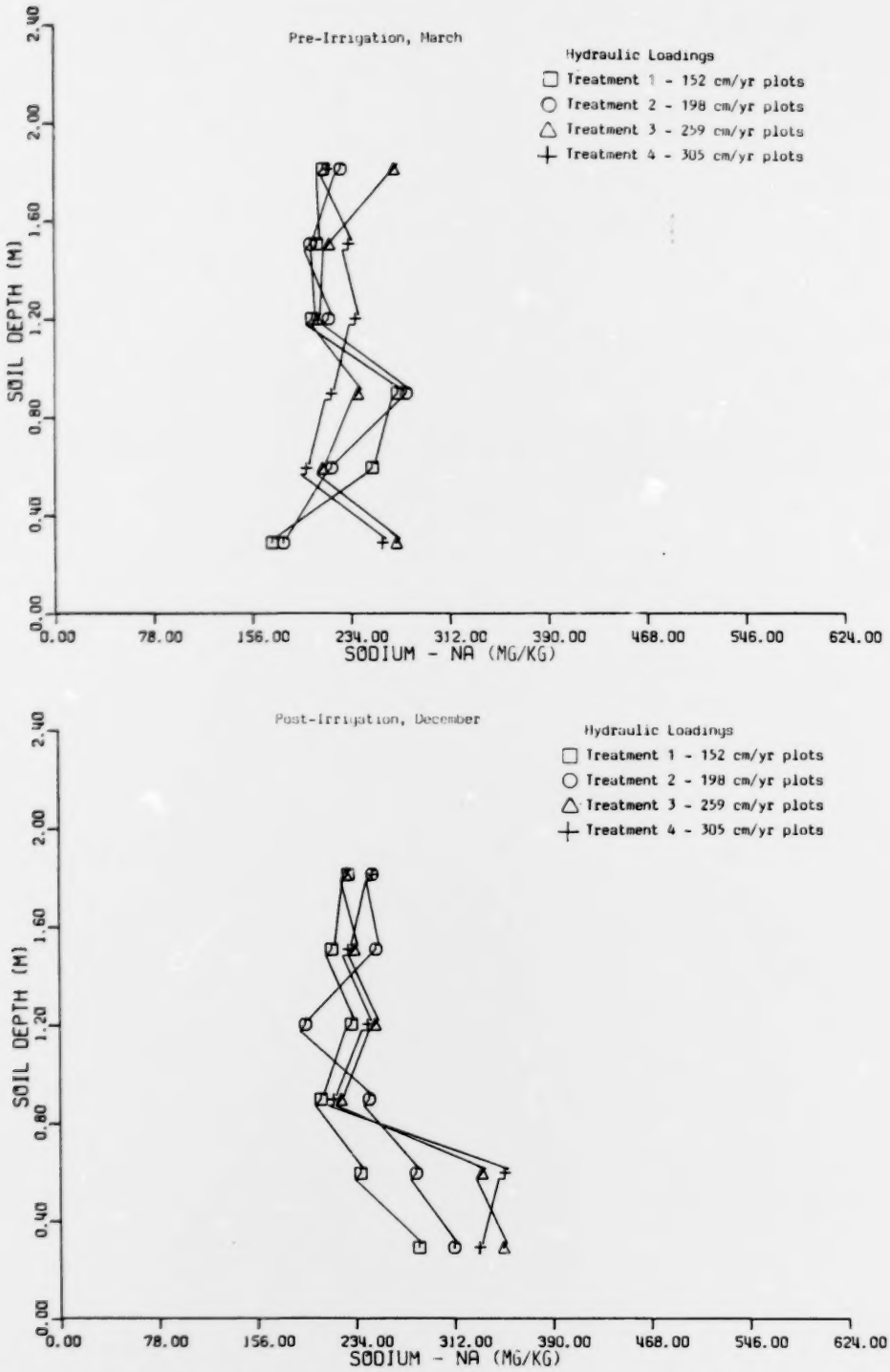
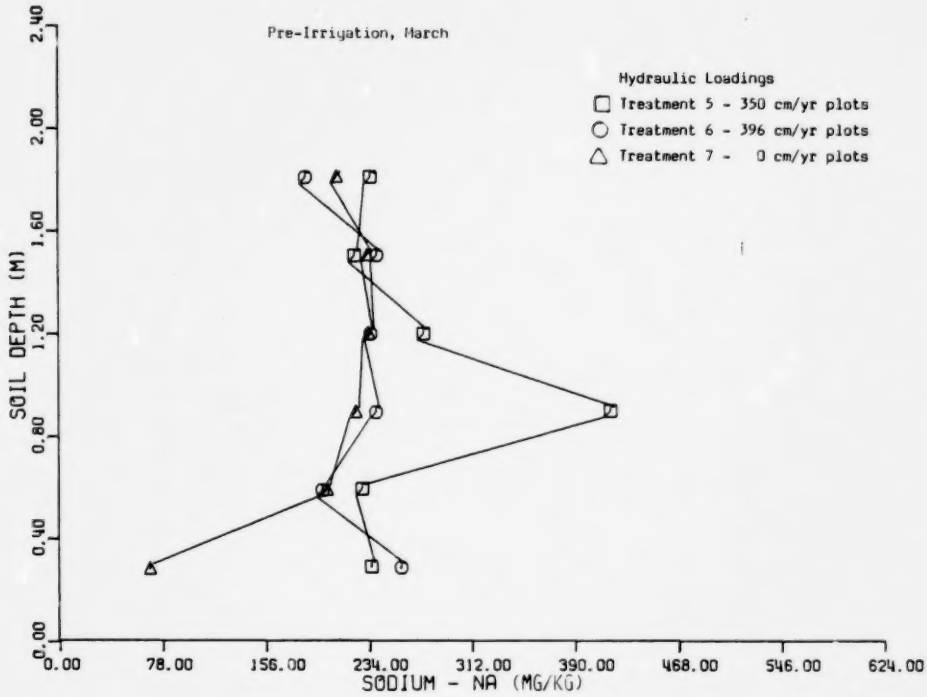


Figure 40. Sodium in Soil Beneath Trial 16000 Bermuda, 1983



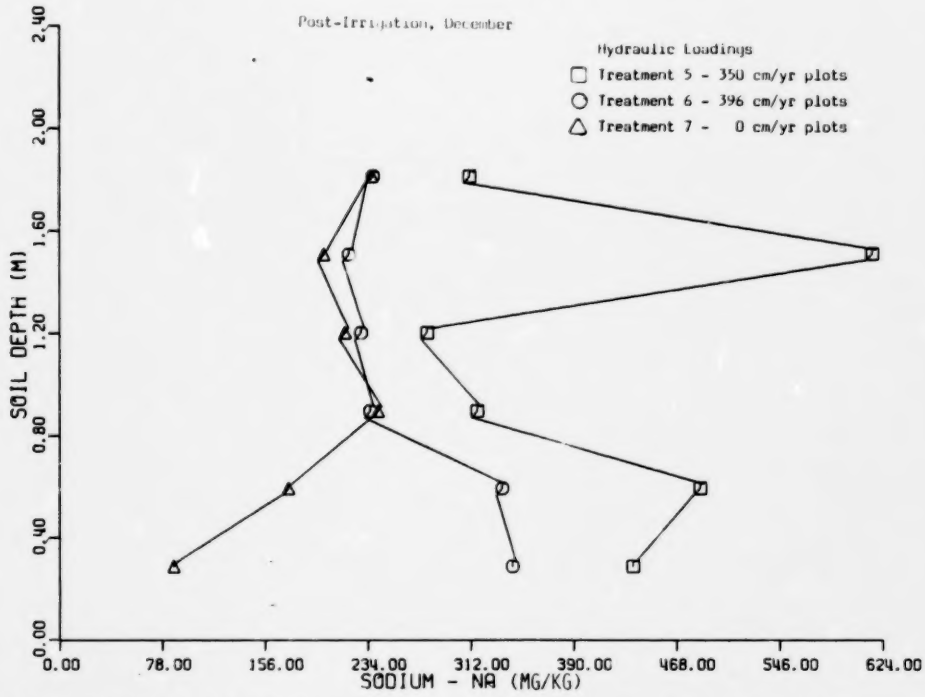


Figure 41. Sodium in Soil Beneath Trial 16000 Bermuda plots, 1983

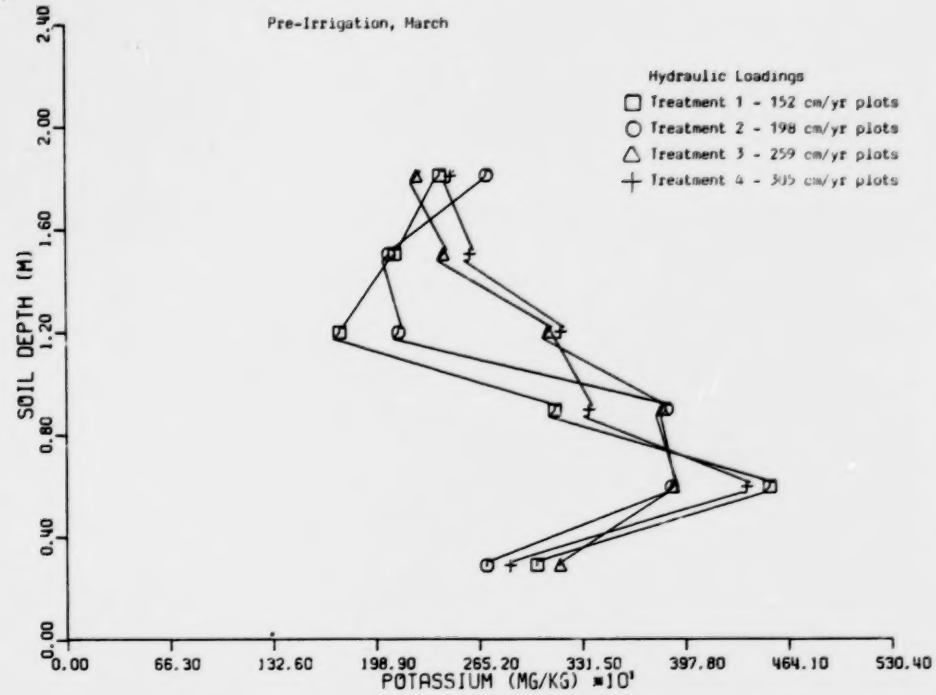
loadings; and high crop evapotranspiration. After the 1983 growing season, the ESP values varied from 4.9 (Treatment 5) to 7.6 (Treatment 2). In addition, the ESP values also increased at the 61 cm depth in Treatments 2 through 6. High concentration of available Ca (11,200 to 14,000 ppm) at depths of 91 cm to 183 cm resulted in lower ESP values at these soil depths. Leaching of Na through the soil profile and the amount of available Ca (0.2 to 1.4 percent) prevented creation of alkali soil (ESP $\geq$ 15) within the upper 61 cm.

Accumulation of potassium within the soil profile was detected in Treatment 1 (Figure 42) and at the 61 cm depth in Treatment 6 (Figure 43). Potassium levels either decreased (Treatments 3 and 4)(Figure 42) or remained relatively constant (Treatments 2 and 5). A potassium mass balance (Table E.22) showed more K applied to the plots than consumed by the crop. Spacial variability in soil potassium levels was reflected in the computed accumulation of K mass of 11,400 kg/ha in Treatment 1 when only 296 kg/ha.yr was applied and 220 kg/ha.yr was removed by crop harvesting. In general, K appeared to be leached past the 183 depth cm within the majority of effluent treated test plots.

As anticipated, chloride and sulfate anions were transported through the 183 cm soil profile in 1983 (Tables E.28 and E.29). From 44 (Treatment 1) to 96 (Treatment 2) percent of the applied chloride mass was apparently removed by deep percolation. Greater than 80 percent of the applied sulfate ion mass was leached past a soil depth of 83 cm. Soil chloride ion concentrations increased within the soil profile within all effluent irrigated plots (Figures 44 and 45). Sulfate ion lens existing at the 152 cm soil depth in Treatments 1 and 2 were apparently leached from the 183 cm soil core and sulfate accumulation was detected within the upper 91 cm of these Treatments (Figure 46). An increase in sulfate concentrations was measured in the soil at the 61 and 91 cm depth in samples collected from all treated plots after the 1983 irrigation season.

Hydraulic Loading Study Summary

Yield data obtained from the grain sorghum (milo) test area indicate milo yield increased as waste water application rate increased up to 3



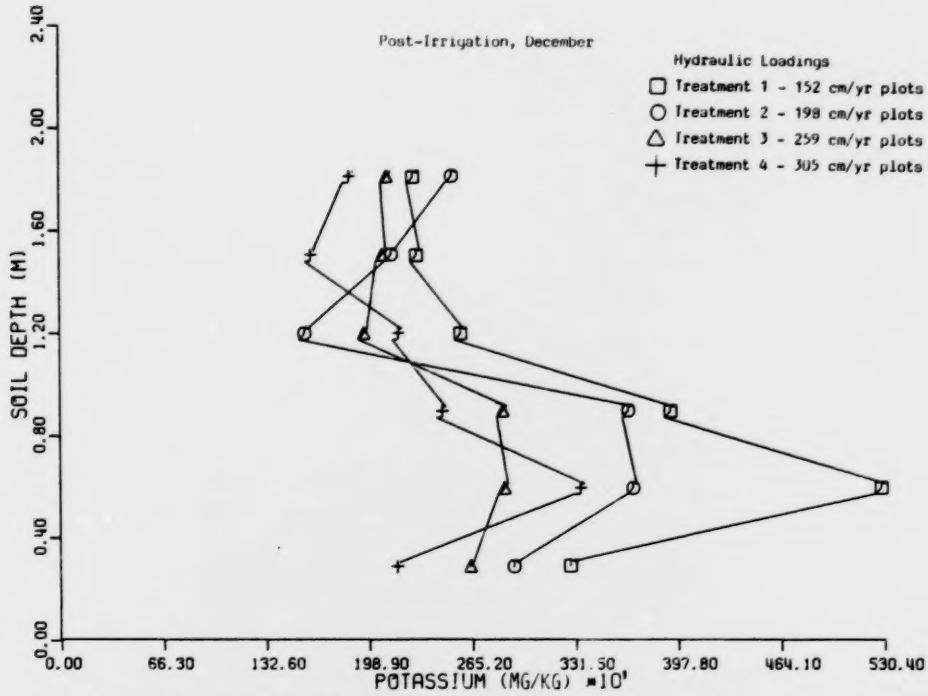
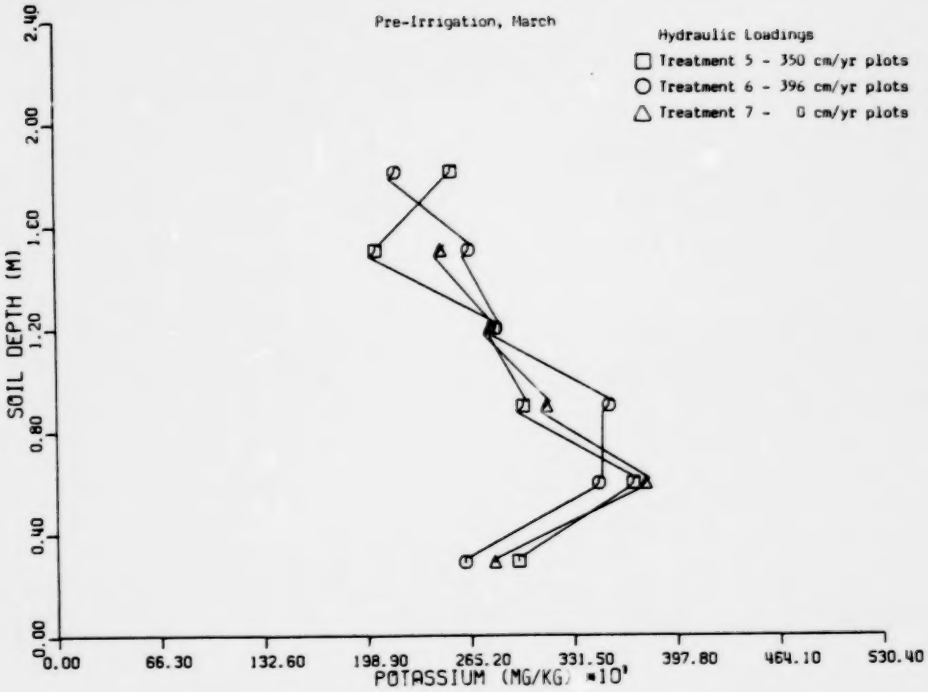


Figure 42. Potassium in Soil Beneath Trial 16000 Bermuda, 1983



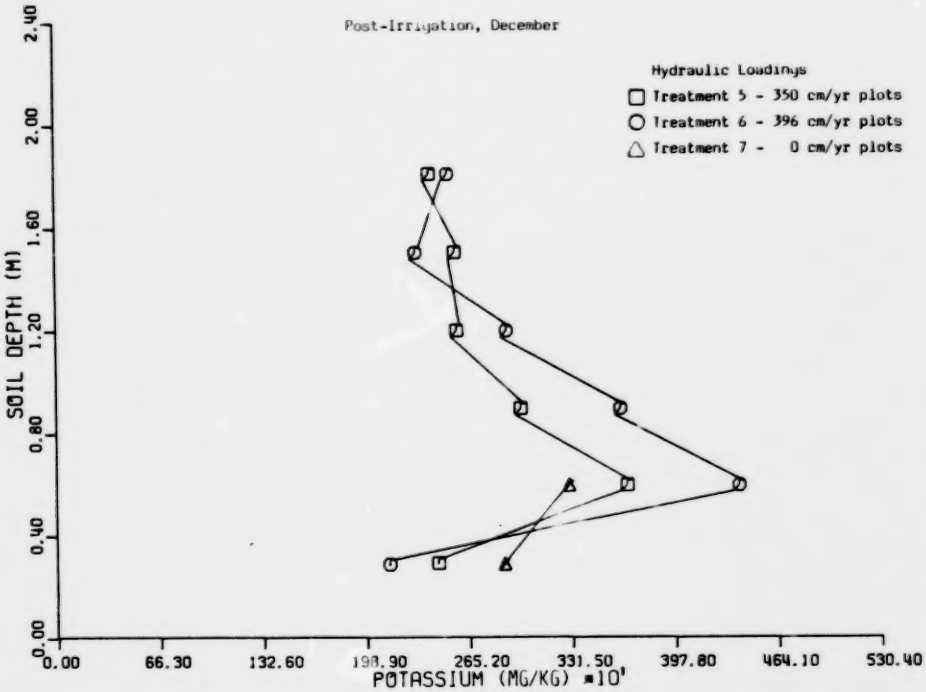


Figure 43. Potassium in Soil Beneath Trial 16000 Bermuda plots, 1983

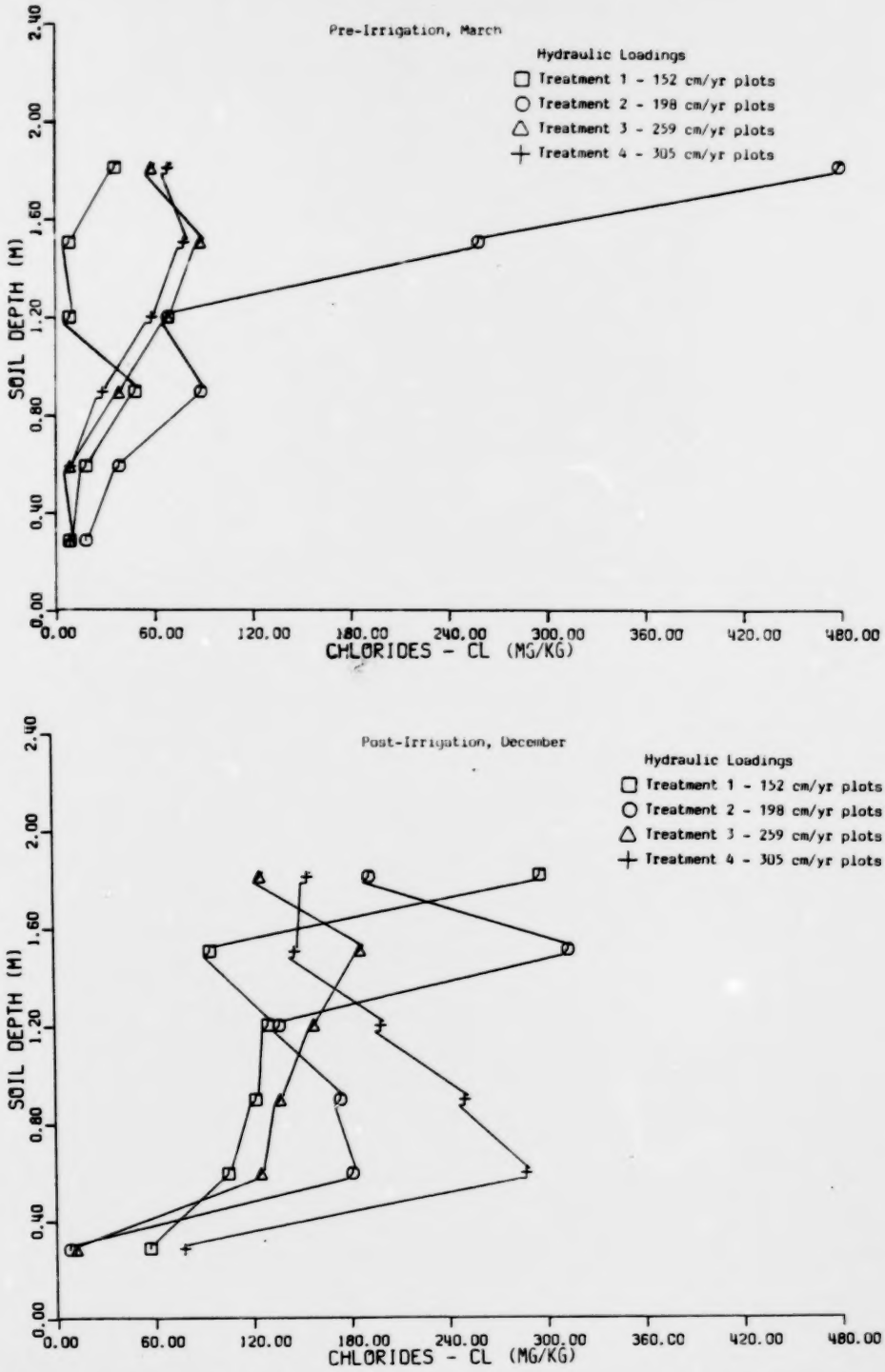
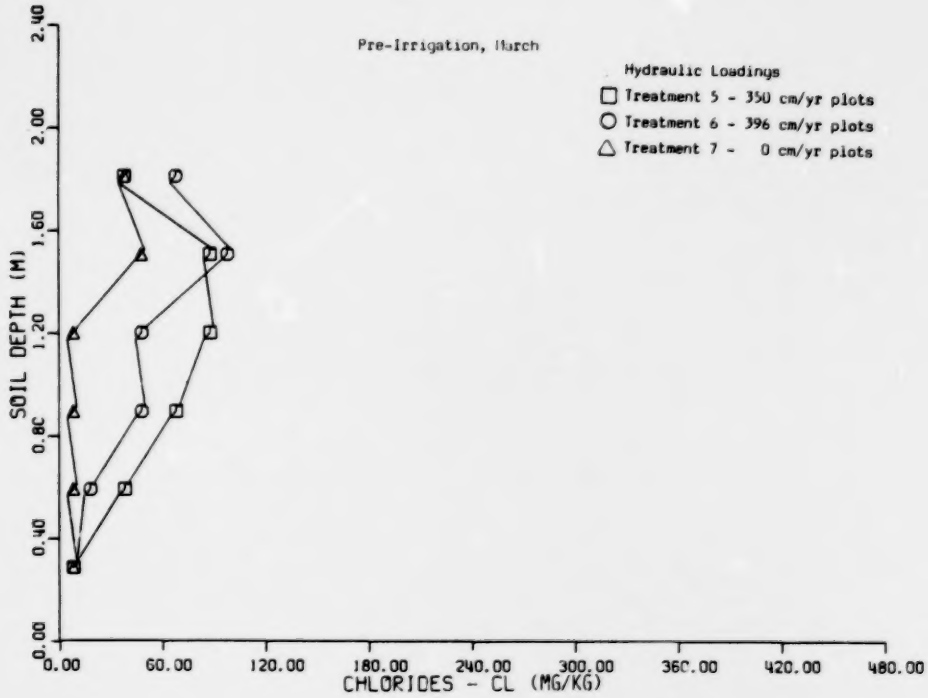


Figure 44. Chlorides in Soil Beneath Trial 16000 Bermuda plots, 1983



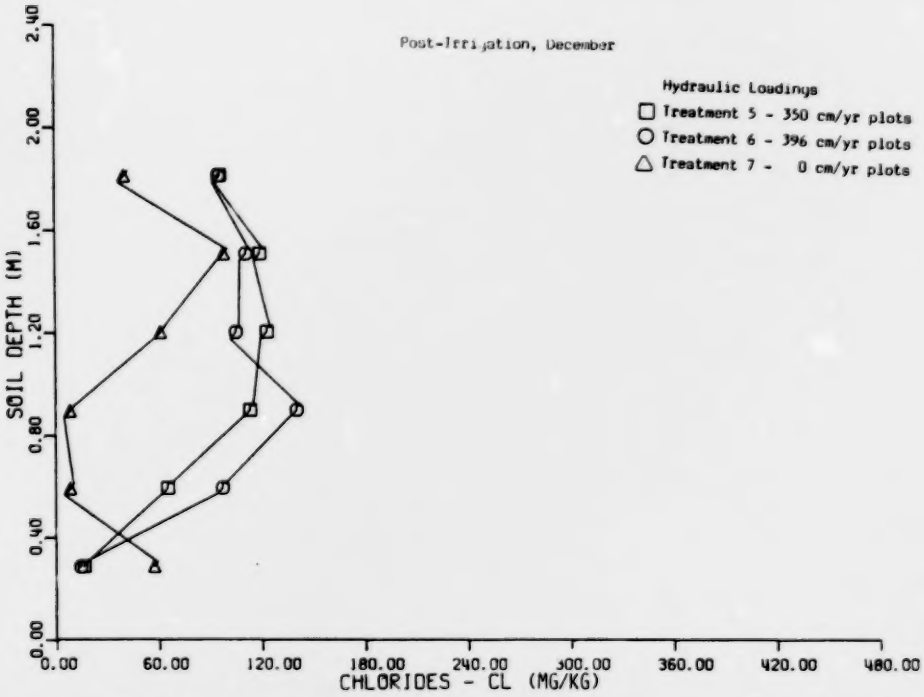
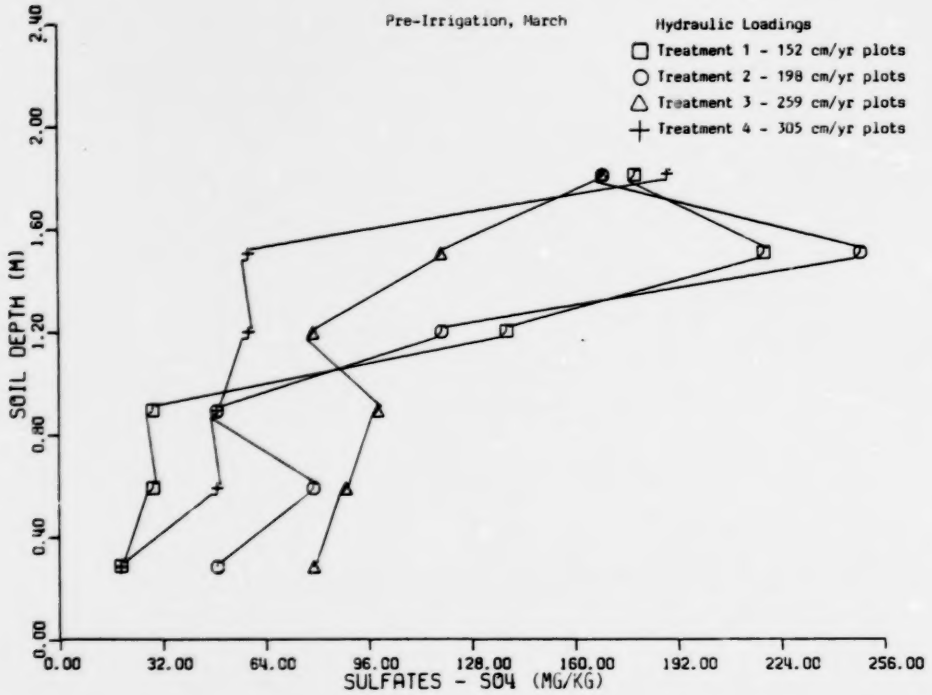


Figure 45. Chlorides in Soil Beneath Trial 16000 Bermuda plots, 1983



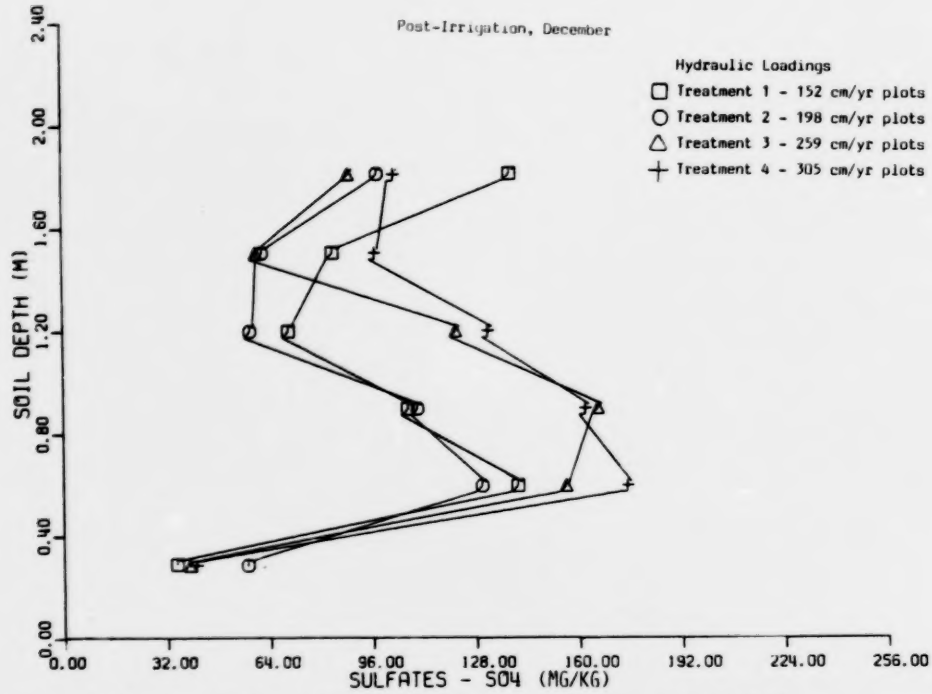


Figure 46. Sulfates in Soil Beneath Trial 16000 Bermuda, 1983

m/yr. High soil moisture in 1982, due to heavy precipitation, produced greater milo yield in the dryland plots than were obtained in the same plots in 1983. Furthermore, in 1982, the milo reduced nutrients and thereby soil fertility to a level which decreased the yield in 1983.

A possible phosphorus deficiency was measured in the seed which may have limited crop yield. Leaching of inorganic nitrogen and sodium salts through 183 cm of the soil profile was computed in test plots irrigated with 137 cm/yr or greater. Exchangeable sodium percentage (ESP) in the soil was less than 7 and limited by deep percolation of sodium.

In 1983, maximum cotton lint yield was produced in plots irrigated with 122 to 297 cm/yr. Excessive top vegetation growth was not observed during the growth season. This may have resulted from decreases in nitrogen availability within the soil profile as the amount of irrigation increased.

The highest nitrogen level in cotton seed tissue was detected in cotton having 51 cm of effluent irrigation in 1983. Leaching of inorganic nitrogen past a soil depth of 91 cm appeared to have occurred as annual hydraulic loadings of 61 cm or greater within the cotton test plots. Annual hydraulic loading rates greater than 122 cm limited accumulation of salts within 183 cm of the soil profile. In the fall of 1983, the ESP values within the top 30 cm of soil collected from cotton test plots irrigated with 183 cm and 297 cm were 9.2 and 8.1, respectively, and may have developed sodic conditions.

Alfalfa produced by wastewater irrigation consistently had greater yields than dryland and freshwater controls. During 1982, alfalfa was harvested only once due to severe climatic conditions. Crop production may have been limited by available phosphorus and potassium in the soil solution. Nitrogen mass balances indicated that all nitrogen mass applied to the alfalfa plots was consumed and nitrogen fixation was a source of inorganic nitrogen for the crop. At hydraulic loading rates greater than 137 cm/yr, all test plots leached dissolved solids through the 183 cm soil profile. ESP levels were less than 10 within the upper 61 cm of soil and appeared to be increasing with sodium mass loading. Sodic conditions may have existed within the upper 30 cm of the plots irrigated with 434 cm/yr.

High water consumption of alfalfa caused accumulations of sodium within the upper 1.8 m of the soil profile at scheduled hydraulic loadings of 137, 198, and 259 cm/yr.

Highest bermuda yields were obtained from the lowest irrigated plot (152 cm/yr). Nitrogen, phosphorus and zinc deficiencies probably limited crop production. Annual hydraulic loading rates of 152 cm or greater leached macro and micro nutrients reducing the availability to the crop of these essential elements. Dissolved solids were transported through 183 cm of soil in all bermuda test plots irrigated with 152 cm/yr or greater. Nitrite/nitrate-nitrogen lens were measured beneath the entire research area. NO_2 + NO_3 levels decreased with depth as hydraulic loadings increased. Leaching, crop utilization and denitrification were primary factors which caused the reduction in NO_2 + NO_3.

HYDRAULIC APPLICATION FREQUENCY STUDY

Trial 17000

The effluent from SeWRP contained approximately 1200 mg/l total dissolved solids (TDS). During the 1982 irrigation season from 12 to 26 cm of effluent and approximately 70 cm of precipitation were applied to the Hancock farm. Total water (including precipitation) applied to the farm in 1983 ranged from approximately 64 to 96 cm. Evapotranspiration (ET) rates are normally greater than 1.22 m/yr (Ramsey and Sweazy 1985). Since ET values are greater than application rates, accumulation of salts in the soil profile will probably occur and eventually may create serious problems with crop production. Several methods have been successfully used to control salts accumulation within the soil root zone (EPA 1978; EPA 1979). Two operation parameters which may aid in the management of salts are the hydraulic loading rate and the frequency of application. The quantity of water applied at any period of time must be controlled to prevent leaching of salts into ground-water sources.

Due to various operational problems, work on Trial 17000 was conducted only during 1982. Even with the limited data base, sufficient informa-

tion was obtained to enable the researcher to develop scenarios as to the effect of hydraulic loading rate and application frequency on crop production and accumulation of salts in soil. Frequency of irrigation and quantity of water applied each irrigation period was presented in Section 4 and in Table 4.

Crop Quantity--

Table 14 presents the quantity of grain sorghum (milo) harvested in 1982. As previously stated, severe weather during May and June ruined the initial crop and the crop was replanted in July. Due to the late planting of grain sorghum, very little grain production developed. Consequently, whole plant biomass is presented as crop production.

Data presented in Figure 47 shows little difference in milo yield produced by applying effluent at frequencies of one application per week and one application per two weeks. A definite increase in crop yields occurred when irrigation frequencies of one application per four weeks and eight weeks were used. Grain sorghum plots treated with 61 cm/yr and 122 cm/yr wastewater at a frequency of one application per eight weeks produced significantly (α = 0.10) greater yields than grain sorghum treatment test plots (Table 14). No significant differences in yield were computed between the 61 cm and 122 cm/yr hydraulic loadings at both the 1 application/4 wk and 1 application/8 week.

Figure 48 shows almost the exact opposite trend with the soybean yields. The highest yield was produced with the more frequent irrigation (Table 15). Soybean yields obtained with 30 cm/yr, and 61 cm/yr at the 1 application/wk were significantly (α = 0.10) greater than yield produced at hydraulic loadings of 122 cm/yr at both the 1 application/4 wk and 8 wk frequencies (Table 15). Furthermore, yield obtained from the test plots irrigated with 61 cm/yr, frequency of 1 application/8 wk was significantly less than the plot irrigated with 30 cm/yr at a frequency of 1 application/wk. However, the soybeans may not have been able to tolerate the longer absences of water and the yields dropped as hydraulic application frequency decreased. In comparison, grain sorghum roots were able to develop to obtain water from greater depths and were more efficient in

TABLE 14. GRAIN SORGHUM BIOMASS PRODUCTION IN TRIAL 17000 - 1982

Treatment	Annual Hydraulic Loading (cm)	Application Frequency Interval (wk)	Yield (kg/ha) Average	Yield (kg/ha) SD	†Significantly Different (α = 0.10)				
1	30.	1	8270.	530.					*
6	61.	2	8530.	1500.					*
5	61.	1	8720.	1210.				*	*
10	122.	2	9150.	1800.				*	*
3	30.	4	9270.	3180.			*	*	*
9	122.	1	9830.	2720.		*	*	*	*
4	30.	8	9930.	2300.		*	*	*	*
7	61.	4	10,900.	3110.	*	*	*	*	
11	122.	4	11,400.	3040.	*	*	*		
8	61.	8	11,900.	1260.	*	*			
12	122.	8	12,300.	5160.	*				

†Treatments with connecting * are not significantly different statistically

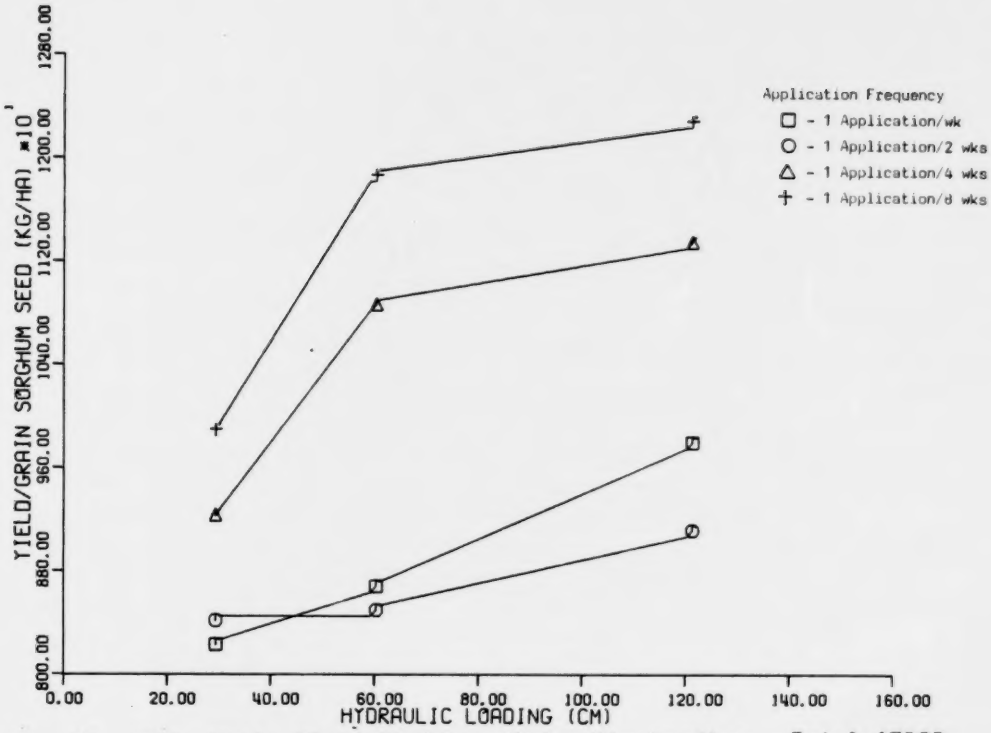


Figure 47. Milo Whole Plant Yield vs Hydraulic Loading - Trial 17000

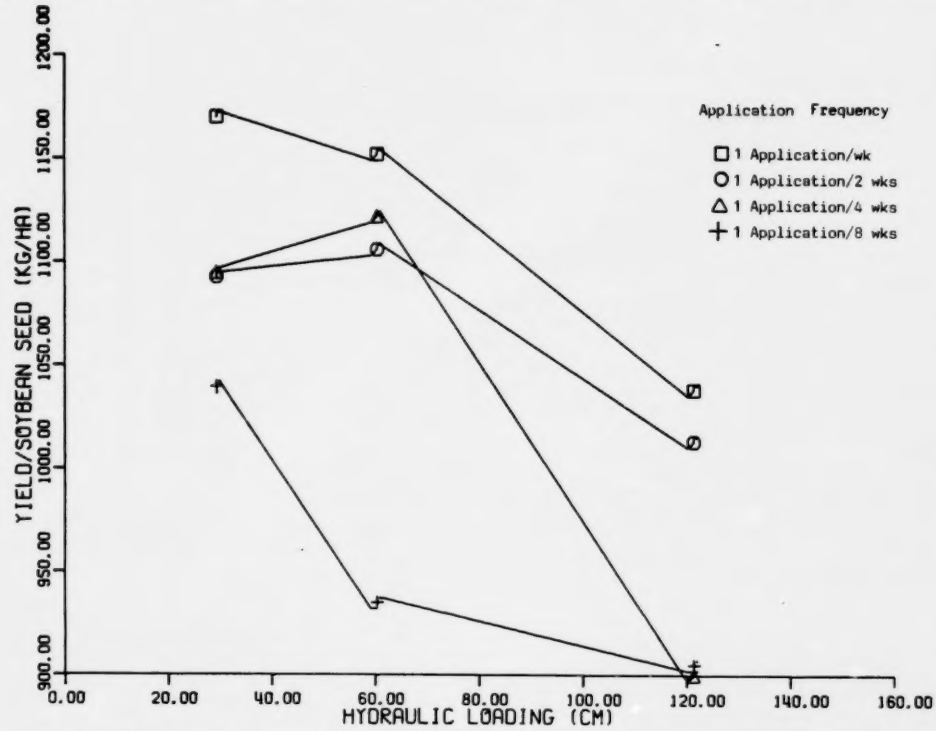


Figure 48. Soybean Seed Yield vs Hydraulic Loading - Trial 17000

TABLE 15. SOYBEAN SEED PRODUCTION IN TRIAL 17000 - 1982

Treatment	Annual Hydraulic Loading (cm)	Application Frequency Interval (wk)	Yield (kg/ha) Average	Yield (kg/ha) SD	†Significantly Different (α = 0.10)		
11	122.	4	902.	134.			*
12	122.	8	907.	264.			*
8	61.	8	937.	150.		*	*
10	122.	2	1020.	311.	*	*	*
9	122.	1	1040.	282.	*	*	*
4	30.	8	1040.	344.	*	*	*
2	30.	2	1100.	358.	*	*	*
3	30.	4	1100.	362.	*	*	*
6	61.	2	1110.	241.	*	*	*
7	61.	4	1120.	234.	*	*	*
5	61.	1	1150.	364.	*	*	
1	30.	1	1170.	274.	*		

† Treatments with connecting * are not significantly different statistically

water use; therefore the crop did better overall when irrigation was less frequent.

Soil moisture data for grain sorghum and soybeans test plots (Figures G.1 through G.4) reinforce the difference in root systems. Compared to soybean plots, the graphs indicate less moisture beneath the sorghum at soil depths of 122, 152, and 183 cm. These soil moisture differences possibly were due to (1) the more extensive grain sorghum root system and (2) the growing season for soybeans ends with a complete shutdown of the plant while the milo plants stay green and continue to extract moisture from the soil until frost kills the crop. In addition, more moisture was retained in the upper 30 cm of grain sorghum plots than soybean test plots irrigated with similar hydraulic loadings at 1 application per two-week, four-week, and eight-week frequencies. This moisture difference may have resulted from a mulching effect from milo crop residues, whereas soybeans have an almost bare ground evaporation rate. This phenomenon involved natural winter precipitation, not irrigation.

Crop Quality--

Soybeans--Table C.6 presents chemical characteristics of soybean stalk and seed tissue. Soybeans harvested from plots irrigated with 30 cm/yr at irrigation frequencies of once per week or once every two weeks contain approximately 80 mg-N/g tissue compared to 98.5 to 110.6 mg-N/g in seed tissue obtained from all other treated plots. TKN levels within the stalk tissue, however, were less in the plots irrigated with 30 cm/yr than plots watered with 61 or 122 cm/yr. TKN levels in the seed tissue obtained from every test plot exceeded normal levels of 30 to 45 mg-N/g tissue (Monson 1978).

Furthermore, phosphorus levels (4.36 to 6.77 mg-P/g) in the seed were greater than reported concentrations of 2.5 to 4.5 mg-P/g tissue at mid to full bloom. Soybeans irrigated with 30 cm/yr contained higher concentrations of P in the seed (6.18 to 6.77 mg P/g)(122 cm/yr) than soybean crops irrigated with 61 or 122 cm/yr. Increased hydraulic loading above 30 cm/yr may have transported dissolved phosphate phosphorus beyond the most active portion of the root zone for extracting nutrients and moisture

(i.e., approximately 70 percent extraction of moisture in the top 50 percent of the root zone).

Similarly, iron concentrations in the stalk tissue were higher in the plants harvested from the 30 cm/yr treatment plots than the remaining test plots (Table C.6). Anaerobic conditions created by application of larger quantities of effluent each irrigation period may have caused reduction of ferric iron to more soluble ferrous iron and transport of iron past the shallow root zone. Likewise, reduction of manganese (Mn) to a more soluble form and transport beyond the crop root zone may have caused the lower levels of Mn in the stalk tissue as hydraulic loadings increased.

Soybean sodium concentration (Figure 49) increased as hydraulic loadings increased at one-week application frequency. At a frequency of 1 application/2 wk, 30 and 61 cm/yr loadings have approximately equal Na concentrations within the stalk. Due to greater mass loadings of sodium, higher Na levels were measured in soybeans irrigated with 122 cm/yr at one application per two weeks. When the application frequency was delayed to one application per four weeks, the quantity of water applied at the 122 cm/yr loading was sufficient to leach Na from the plant root zone. Apparently the extreme drying conditions encountered with an eight week application frequency inhibited leaching in all test plots except the 122 cm/yr loading. At the 30 and 61 cm/yr loadings, Na concentrations remained high since the applied water was retained and used within the root zone. Figure 49 shows the same trends in Na concentration within the seed.

Grain Sorghum--

Table C.5 presents certain quality characteristics of the harvested grain sorghum crop. At an effluent irrigation frequency of one application per eight weeks, nitrogen levels were less than the concentration measure in tissue irrigated once every four weeks (Figure 50). A similar trend was observed with phosphorus levels within plant tissue watered with 30 cm/yr. Crops produced in test plots spray irrigated with 61 and 122 cm/yr exhibited a lower phosphorus content as the irrigation frequency decreased from one application per week to one irrigation every two weeks (Figure 51). With longer intervals between irrigation, however, phos-

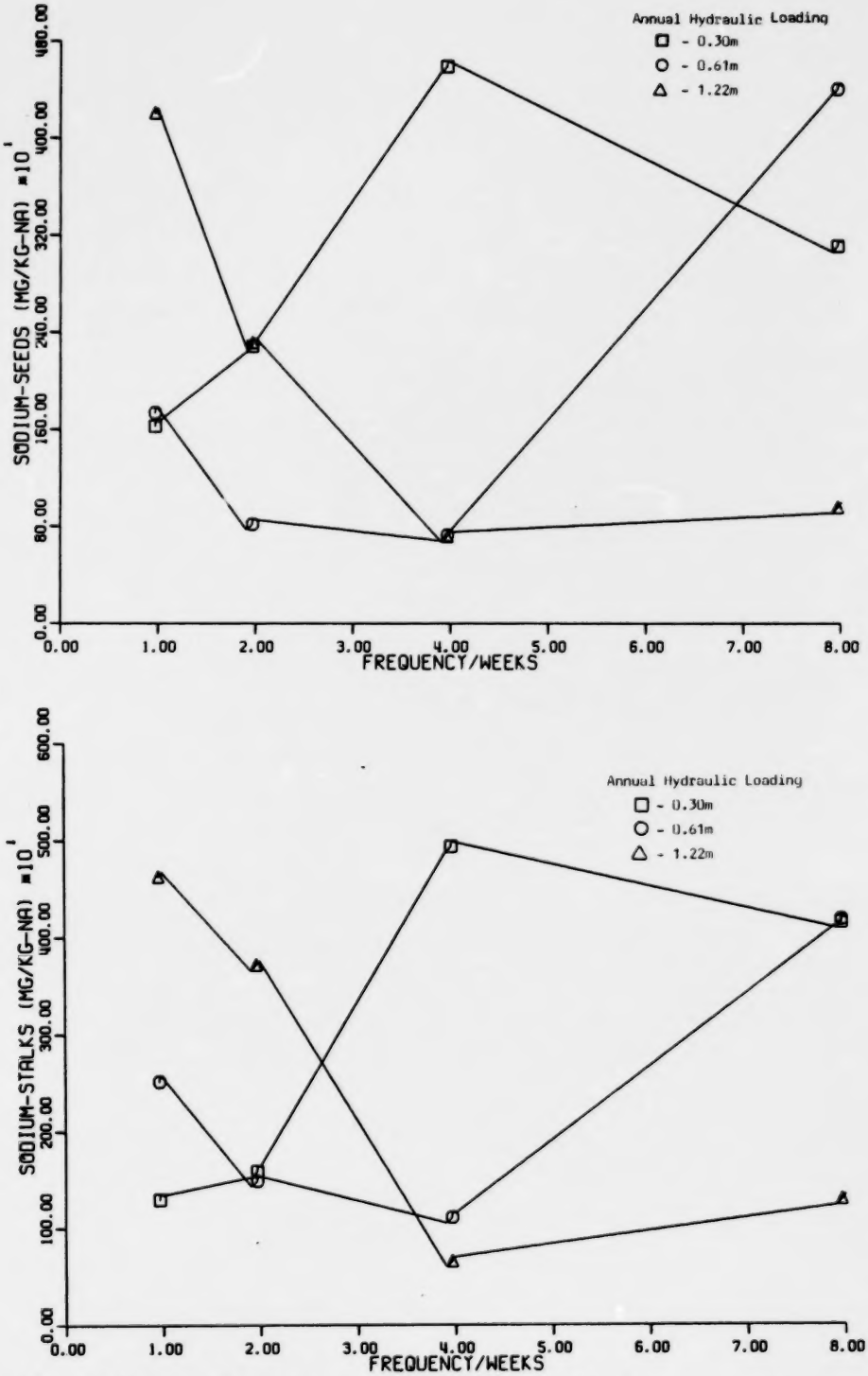


Figure 49. Sodium vs Frequency - Trial 17000 Soybeans

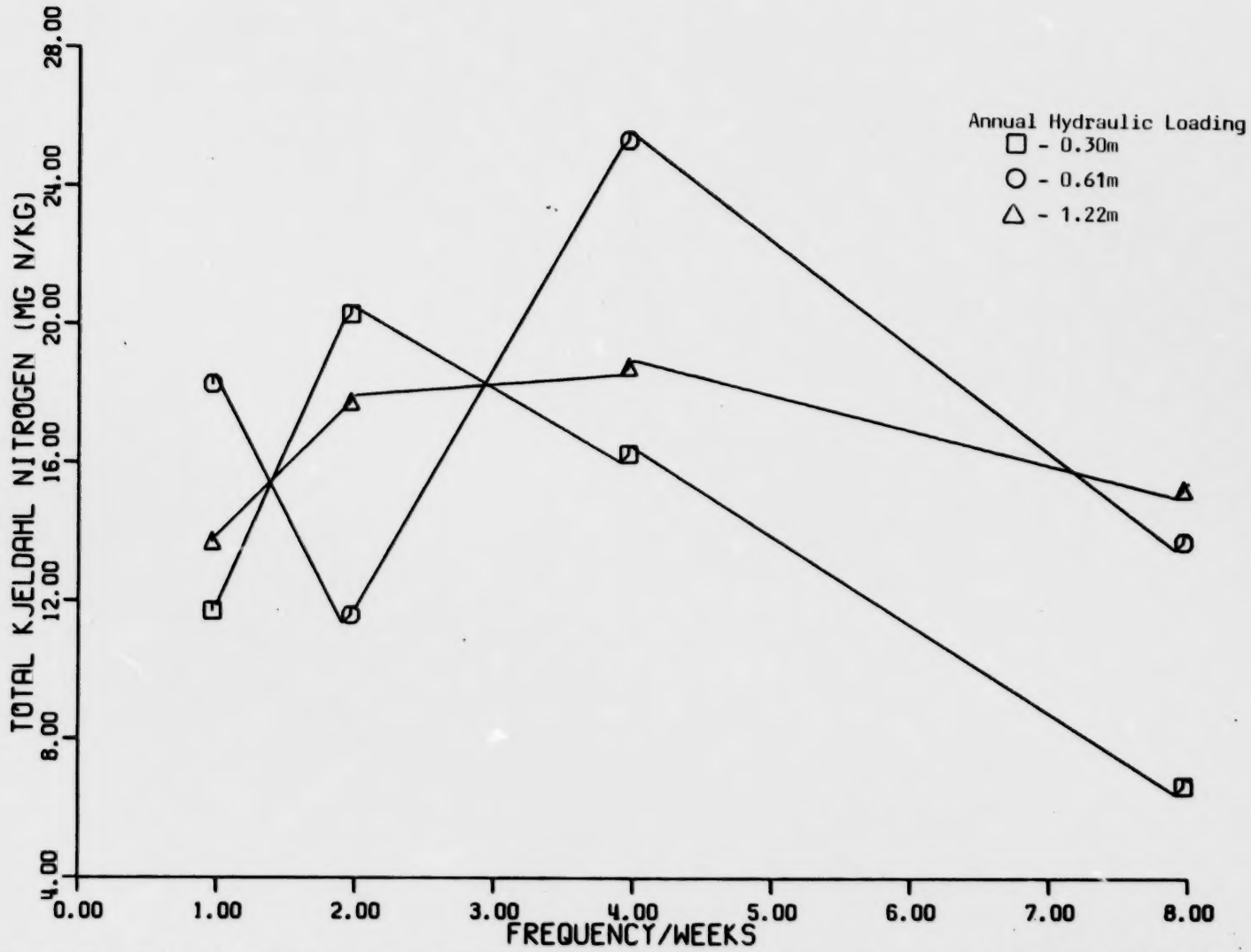


Figure 50. Total Kjeldahl Nitrogen (TKN) in Plant Tissue vs. Frequency of Irrigation for Trial 17000 Grain Sorghum plots

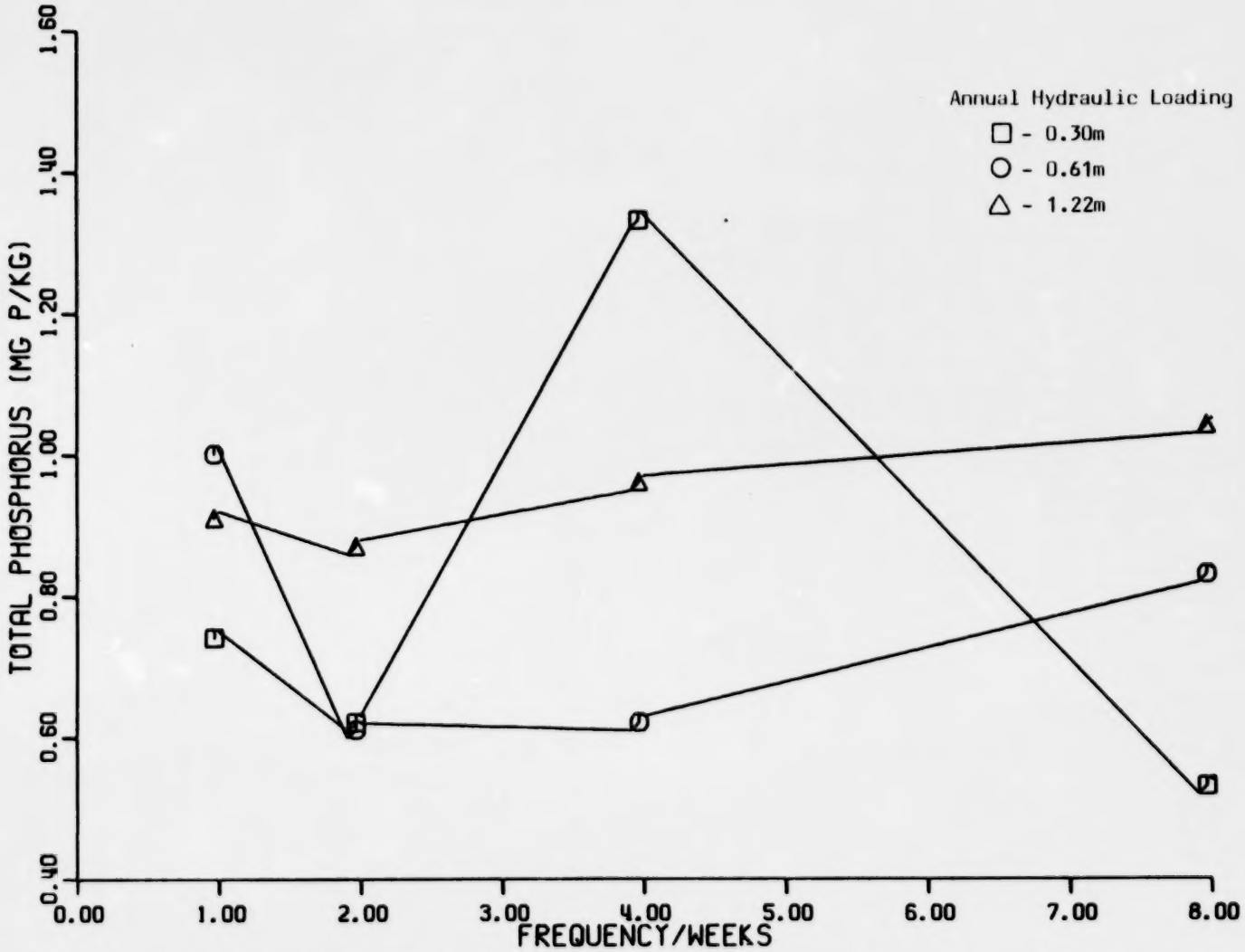


Figure 51. Total Phosphorus (TP) in Plant Tissue vs. Frequency of Irrigation for Trial 17000 Grain Sorghum Plots

phorus levels within the crop increased.

More nitrogen and phosphorus mass were available to the grain sorghum irrigated with 61 and 122 cm/yr and, consequently, higher concentrations of these elements were measured in the plant tissue. Longer time intervals between irrigation events required larger quantities of effluent to be applied to the plots during each irrigation period; therefore, there existed a greater potential for nitrogen leaching past the effective nutrient uptake portion of the root zone.

Variation of potassium content in grain sorghum tissue harvested from Treatments 1 through 4 (30 cm/yr hydraulic loading) was erratic (Figure 52), ranging from 6400 to 16,200 mg/kg plant tissue (an average of 11,600 $\pm$ 4,440 mg K/kg tissue). Except for K content of grain sorghum harvested from Treatment 5 (9300 mg-K/kg tissue), test plots irrigated with 61 cm of effluent in 1982 produced a crop containing relatively stable K concentration (11,700 $\pm$ 550 mg K/kg tissue). With annual hydraulic loadings of 122 cm, K levels in crops harvested from Treatments 9 and 10 were 16,100 and 5000 mg/kg tissue, respectively. As the interval between irrigation periods increased from 4 to 8 weeks, the K concentration in the sorghum tissue increased approximately 2000 ppm. Potassium concentrations in plant tissue were approximately equivalent in Treatment 8 (61 cm/yr, one application/8 weeks) and Treatment 12 (122 cm/yr, one application/8 weeks).

Grain sorghum accumulated sodium when treated with 30 cm/yr regardless of how infrequent the application (Figure 53). The 61 cm/yr loading showed an almost constant level of Na The 122 cm/yr loading appeared to have leached some Na below the root zone, thereby decreasing its availability and plant utilization.

Soils

Nitrogen--

Figures G.5 through G.8 illustrate the levels of NO_2 + NO_3-N throughout the upper 183 cm of the soil profile. Within the grain sorghum plots the crop was apparently utilized most of the nitrogen applied to the test plots at the hydraulic loadings of 30 cm/yr to 122 cm/yr. As the

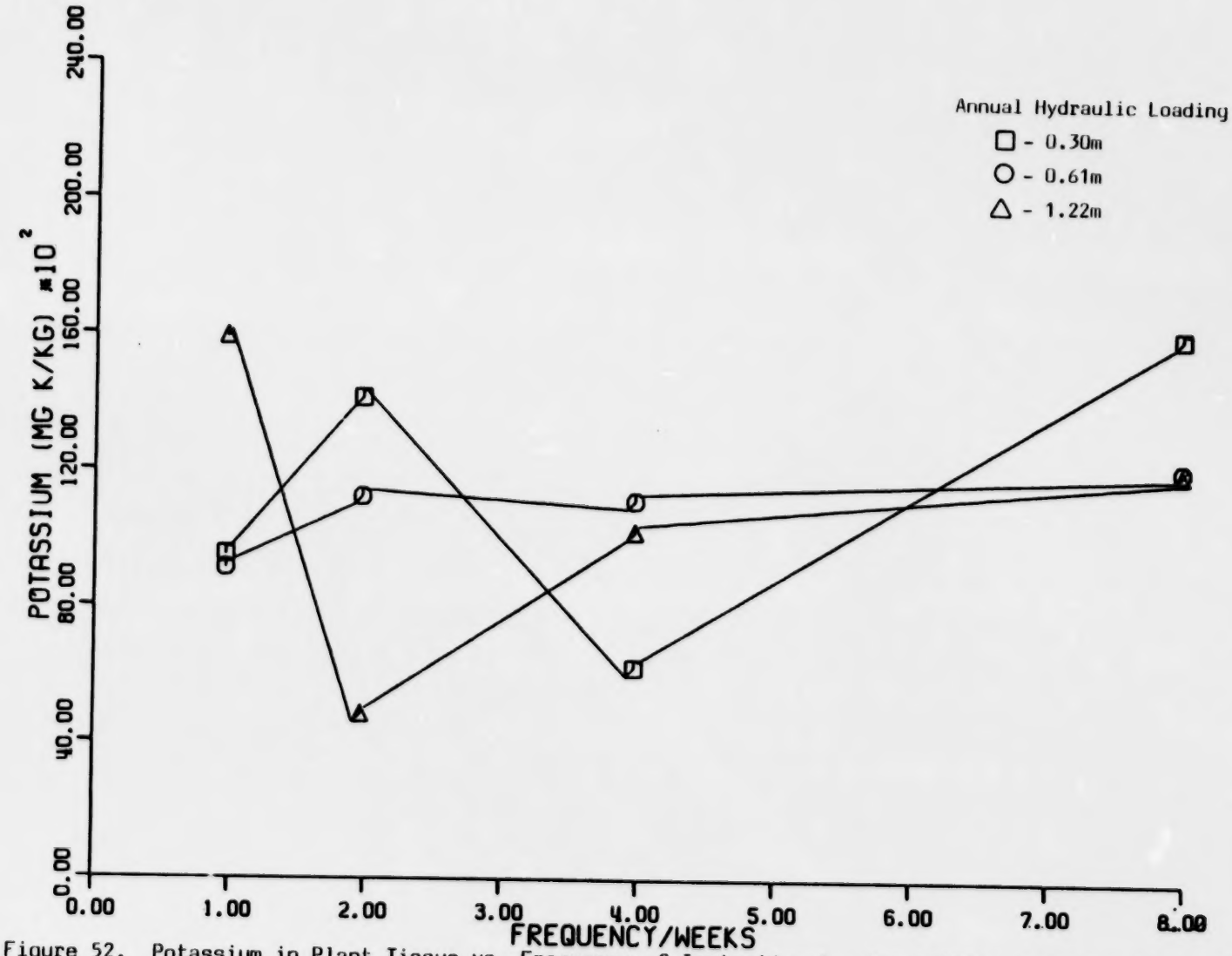


Figure 52. Potassium in Plant Tissue vs. Frequency of Irrigation for Trial 17000 Grain Sorghum plots

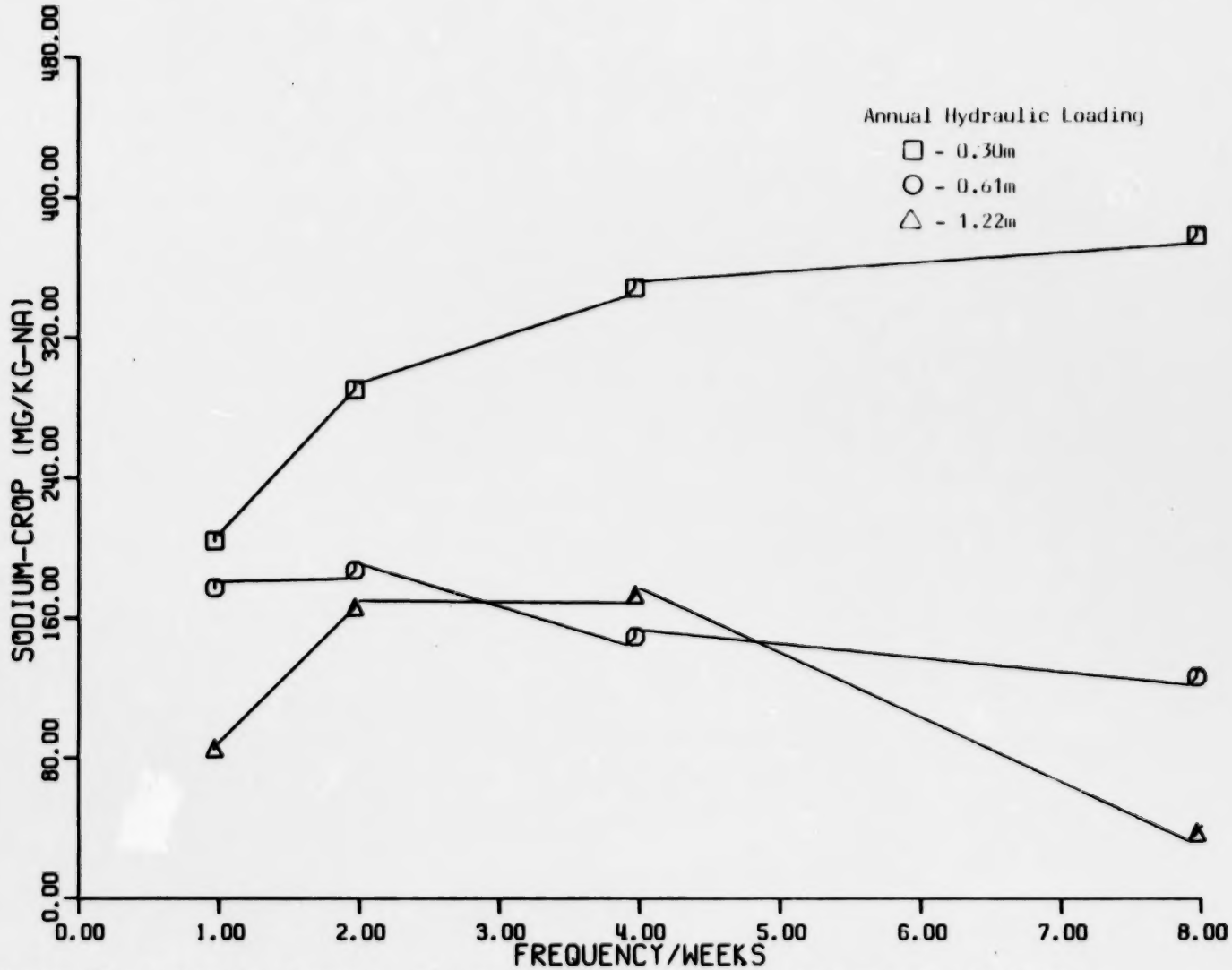


Figure 53. Sodium vs. Frequency of Irrigation for Trial 17000 Grain Sorghum Whole Plant

hydraulic loading increased from 30 cm to 122 cm/yr, NO_2 + NO_3 nitrogen accumulated within the profile at depths of 122 cm, 152 cm, and 183 cm. At the 61 cm/yr hydraulic loadings, the data indicate NO_2 + NO_3-N was reduced throughout the profiles with decreasing frequency of application. No difference in NO_2 + NO_3-N levels with depth or between the 30 cm/yr and 61 cm/yr loading was observed once the application frequency decreased to one application/4 wk (Figure G.6). Possibly the more frequent the effluent application, the more shallow the grain sorghum root depth; consequently, the less utilization of nitrogen with greater soil depths. Furthermore, as hydraulic loadings were increased, NO_2 + NO_3-N was transported past the shallow root system. As the frequency of application was decreased (i.e., one application/4 wk or 8 wk) the roots penetrated the soil to a greater depth and consequently had access to more moisture and NO_2 + NO_3-N.

Since smaller quantities of effluent were applied per application period at the higher application frequencies (i.e., one application/1 wk and 2 wk), a higher percentage of evaporation losses could have caused less water to be available to the plants. Under these conditions, nitrogen within the upper 61 cm would be utilized by the crop. At the 2 wk application frequency, little difference in NO_2 + NO_3-N within the top 91 cm was observed as the effluent loading rate increased (Figure G.5).

Soybeans have a taproot from which smaller branches extend outward ending finally in feeder roots. When the application frequency decreased, the root system failed to utilize the available NO_2 + NO_3 and consequently NO_2 + NO_3 levels within the soil profile increased (Figures G.7 and G.8).

Nitrogen mass balances were conducted on the upper 91 cm of soil within each test plot. Initial conditions and coefficient values for equation 3 are presented in Tables D.5 and D.6 for grain sorghum and soybeans, respectively. Grain sorghum irrigated with 30 cm/yr at application frequencies of one per week (Treatment 1), one per two weeks (Treatment 2) and one per four weeks (Treatment 3) consumed 98.3 to 152.2 kg-N/ha.yr of the approximately 108 kg-N/ha.yr applied through effluent irrigation (Figure 54). Besides nitrogen uptake by the crop, denitrification appeared to be the only other major mechanism for nitrogen removal from the soil matrix in these treatments. Low nitrogen consumption by grain sorghum was

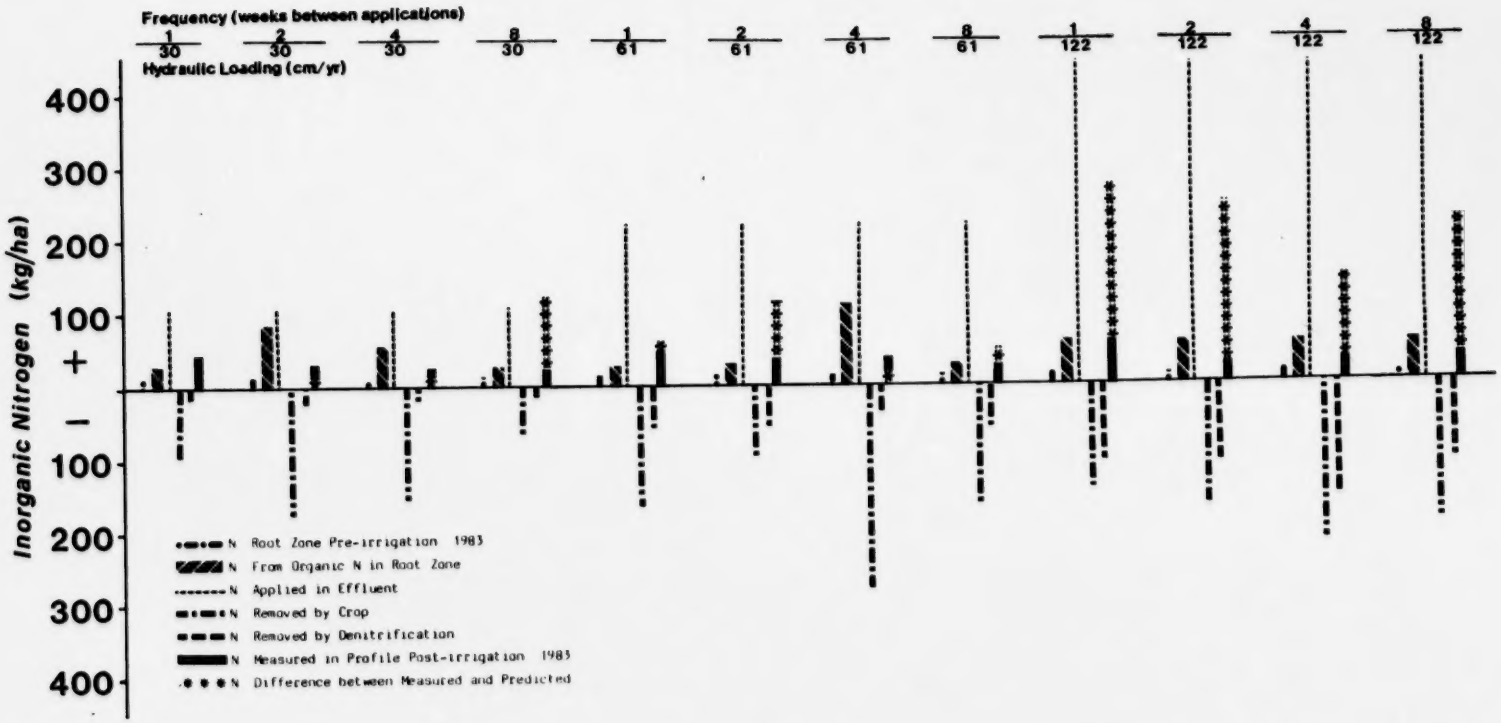


Figure 54. Nitrogen Mass Balance for Trial 17000 Grain Sorghum Plots

obtained in Treatment 4 (30 cm/yr, 1 application/8 wk) which may have resulted from leaching of nitrogen beyond the effective uptake portion of the root zone. Transport of inorganic nitrogen past 91 cm was not observed in grain sorghum test plots irrigated with 61 cm/yr at frequencies of one application per week, and one application per four weeks (Figure 54). Inorganic nitrogen was leached beyond 91 cm of the soil profile when 61 cm was applied to grain sorghum at one irrigation every eight weeks. Regardless of irrigation frequency, annual hydraulic loading of 122 cm produced leaching of inorganic nitrogen past the 91 cm soil depth.

Nitrogen fixation apparently effected the inorganic nitrogen pool within the top 91 cm of soil in every soybean test plot irrigated with 30 cm of effluent per year. The soil microflora may have influenced the need for symbiotic nitrogen fixation by immobilizing some of the inorganic nitrogen. The possibility of nitrogen immobilization was supported by the measured increase in organic nitrogen within the 91 cm soil profile after the 1982 irrigation season.

Once the nitrogen mass loading increased to 220 kg-N/ha.yr (61 cm/yr), N_2 fixation was inhibited. The major mechanisms for nitrogen removal within plots irrigated with 61 cm/yr was through crop harvest (Figure 55). Inorganic nitrogen not removed by crop uptake or denitrification was mainly stored in the upper 91 cm of soil in Treatment 6 (61 cm/yr, one application/2 wk) and Treatment 7 (61 cm/yr, one application/4 wk). Due to the large quantities of effluent (approximately 30 cm) which were applied during each irrigation event, inorganic nitrogen was leached beyond 91 cm in Treatment 8 (61 cm/yr, one application/8 wk).

Soybean blooming and maturity is a function of the length of daylight. Consequently, soybeans planted in July 1982 grew and their fruit and seeds matured at a faster rate (due to daylight conditions) than the grain sorghum crop. Water consumption rates of soybeans was also possibly greater than grain sorghum requirements at specific times during 1982. The increased soybean water requirement may have resulted in the accumulation of inorganic nitrogen within the upper 91 cm in Treatment 9 (122 cm/yr, one application/week). Smaller quantities of effluent applied every week may have promoted shallow root development. A shallower root

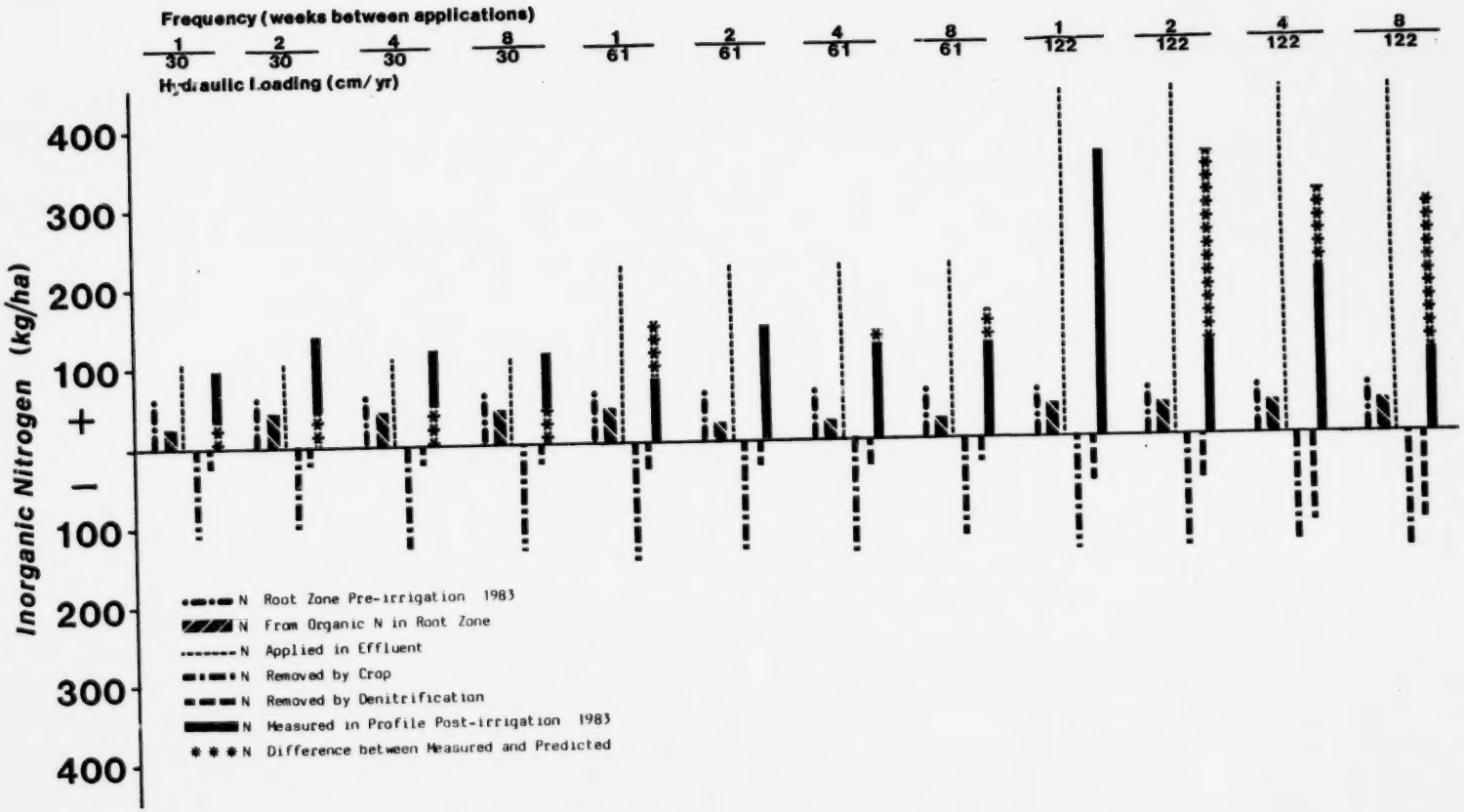


Figure 55. Nitrogen Mass Balance for Trial 17000 Soybean Plots

zone in conjunction with greater water requirement (more mature crop) possibly utilized most of the available water in the root zone thereby preventing leaching of inorganic nitrogen past 91 cm of soil (Figure 55). Except for Treatment 9, inorganic nitrogen apparently was leached beyond a depth of 91 cm within soybean test plots irrigated with 122 cm/yr at frequencies of one application per two, four, and eight weeks.

Phosphorus--

Phosphorus removal by grain sorghum (5.3 to 12.9 kg-P/ha) and soybeans (6.8 to 8.8 mg-P/ha) was less than cited consumption rates of 15 kg/ha.yr and 10 to 20 kg/ha.yr, respectively (EPA 1981). Since the increase in soil TP during 1982 was greater than the mass applied (Table E.5), the accumulation of TP measured in the upper 91 cm of the sorghum test plots in November 1982 apparently was a spurious result due to spacial differences in phosphorus levels within the test plots. Similarly, the apparent leaching of phosphorus past 91 cm of the soil profile of the soybean plots (Table E.6) was a false indication of the treatment affect on phosphorus movement in the soils. With approximately 2.5 cm of water applied each week to soybeans in Treatment 1, an average weekly net evaporation rate of 2.8 cm, and the chemical characteristic of the soil, percolate transport of 68 to 409 kg-P/ha beyond 91 cm most likely did not occur.

Dissolved Solids--

Total dissolved solids (TDS) leached to soil depths greater than 91 cm in all test plots as the annual hydraulic loading was increased from 30 cm/yr to 61 cm/yr and 122 cm/yr (Tables E.11 and E.12). Within the soybean test plots as the application interval increased, more TDS was accumulated in the top 91 cm of soil.

In soils collected from the soybean test plots the sodium (Na) concentration increased from 30 cm depth to a maximum concentration at the 61 cm depth (Figures G.9 and G.11). Whereas, in the grain sorghum plots maximum sodium concentrations were measured at depths of 91 cm (Figures G.12 and G.14). In general, as annual hydraulic rate increased from 30 cm/yr to 61 cm/yr, the Na concentration at the 61, 91, and 122 cm depths in-

creased. Leaching of salts from the 183 cm soil profile in plots irrigated with 122 cm/yr prevented further accumulation of sodium. Only in soybean test plots, application frequency did not appear to affect the soil Na concentration profile at hydraulic loadings of 30 and 61 cm/yr (Figures G.9 and G.10). An application frequency of 1 irrigation/2 wk, at a hydraulic loading of 122 cm/yr produced a noticeable increase in Na concentration at the 91 to 183 cm depths compared to other application frequencies at the same annual loading.

Application frequency may have had an effect on sodium levels in the upper 91 cm of the sorghum test plots irrigated with 30 cm of effluent in 1982 (Figure G.12). Low weekly effluent applications produced greater Na concentrations in the upper 91 cm of soils on Treatment 1 of the grain sorghum test plots. As the wastewater application interval increased to once every two weeks and four weeks, Na concentrations in the first 91 cm of soil decreased. With the high Na mass loading (3855 kg/ha) to plots irrigated with 122 cm/yr, an increase in soil Na levels was observed at soil depths of 61 and 91 cm.

In general, Na levels were higher throughout the entire 183 cm soil profile in sorghum test plots having 61 cm of effluent applied in 1982 (Figure G.13). Increase in time intervals between irrigation events resulted in larger quantities of water applied during each wastewater application event and accumulation of Na primarily at the 91 and 122 cm depth. Once the wastewater application interval was extended to once every four weeks, lower Na levels were observed from 61 to 183 cm of soil than measured in the higher effluent application frequencies. Treatment 8 in the grain sorghum test plots experienced high mass loading of Na (1930 kg Na/ha) and leaching of Na past 183 cm soil depth; consequently, an apparent increase in Na concentration was detected within the soil profile. Soil Na concentrations, however, were not as high as concentrations measured in Treatments 5 and 6 in soil samples obtained at depths of 91 to 183 cm.

Leaching of Na through the 183 cm soil profile was the major mechanism controlling the levels of Na in the soils beneath grain sorghum irrigated with 122 cm/yr (Figure G.14). In general, the highest Na concentra-

tion was measured at the 91 cm depth which was in close proximity to the upper portion of the caliche soil layer existing beneath the area.

Maximum ESP values (all less than 5) were obtained in the top 30 cm of the soybean test plots (Figures 56 and 57). As the application interval increased, the ESP values within the soil profile decreased. Soybeans consumed water primarily in the upper 61 cm of soil; therefore, generally the highest exchangeable Na percentage occurred at these depths. Upward migration of water due to capillary action during water stress periods (increased time intervals between irrigation) caused an increase in Na in the upper profile. This phenomenon was quite pronounced in the soybean plots with 122 cm hydraulic loading (Figure 57). As previously mentioned, the stage of crop maturity also affects water consumption. The higher Na percentage values (ESP values) with soybean plots irrigated with 122 cm/yr than grain sorghum plots subjected to the same irrigation condition may have been caused by the higher water consumption within the top 91 cm by the more mature soybean crop. This phenomenon is shown in Figure 57 for wastewater application periods of once every week and once every four weeks. Furthermore, the effects of greater water consumption by soybeans appeared to have affected the ESP values within the 30 cm/yr test plots at one application every four weeks.

In contrast, the less mature grain sorghum developed a deeper root system and possibly consumed less water during the shortened growing season than soybeans. Consequently, percolate transported Na to greater depths within the soil profile. In general, ESP values were below 2 (Figures 58 and 59). Soils in grain sorghum test plots irrigated with 30 cm of effluent per year showed a decrease in ESP values as the frequency of application was decreased from one irrigation per week to one irrigation every four weeks (Figure 58). With a higher annual hydraulic loading of 122 cm, ESP values throughout the soil profile were at the lowest level of approximately 1 in test plots irrigated once every four weeks (Figure 59). As the irrigation frequency was decreased from one application per four weeks to one application per eight weeks, the ESP values did increase and were fairly uniform throughout the upper 152 cm soil depth.

Potassium concentrations within the soil profile beneath the grain

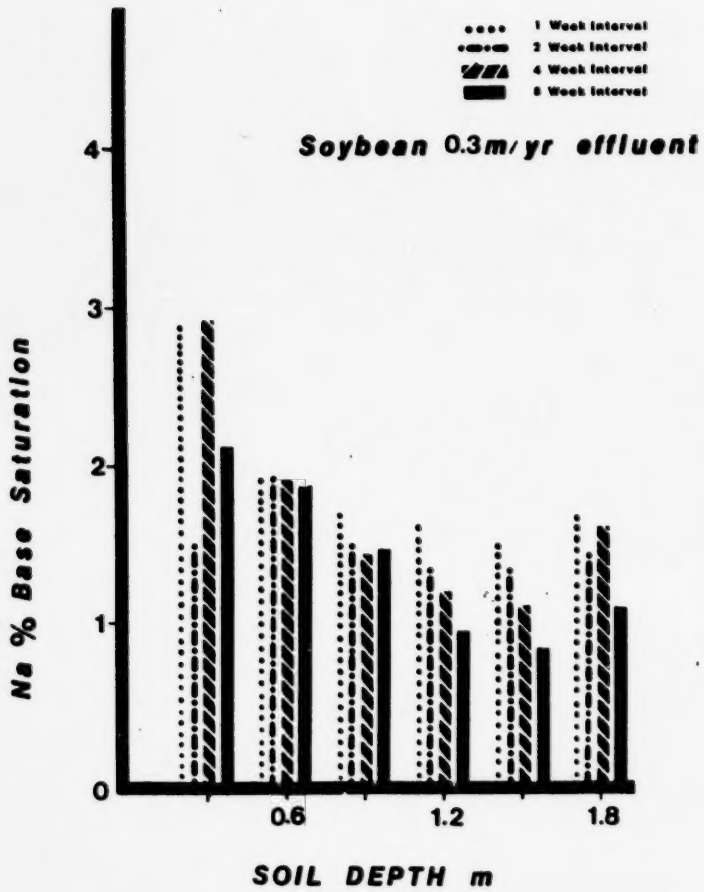


Figure 56. Na % Base Saturation at various depths for varying applications per week and an annual effluent loading of 0.3 m on Soybean Test plots, Trial 17000

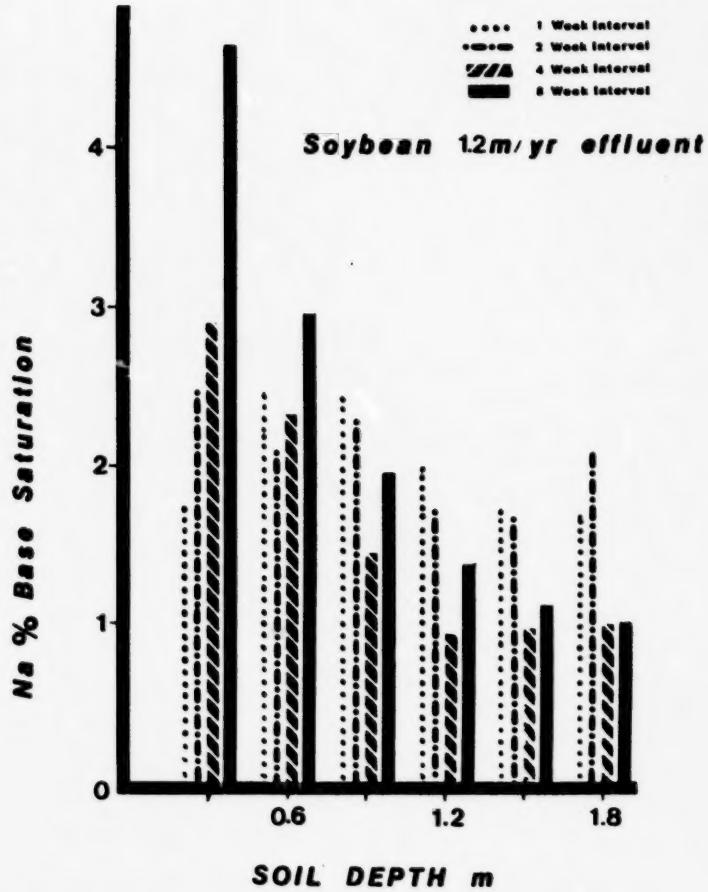


Figure 57. Na % Base Saturation at various depths for varying applications per week and an annual effluent loading of 1.2 m on Soybean test plots, Trial 17000

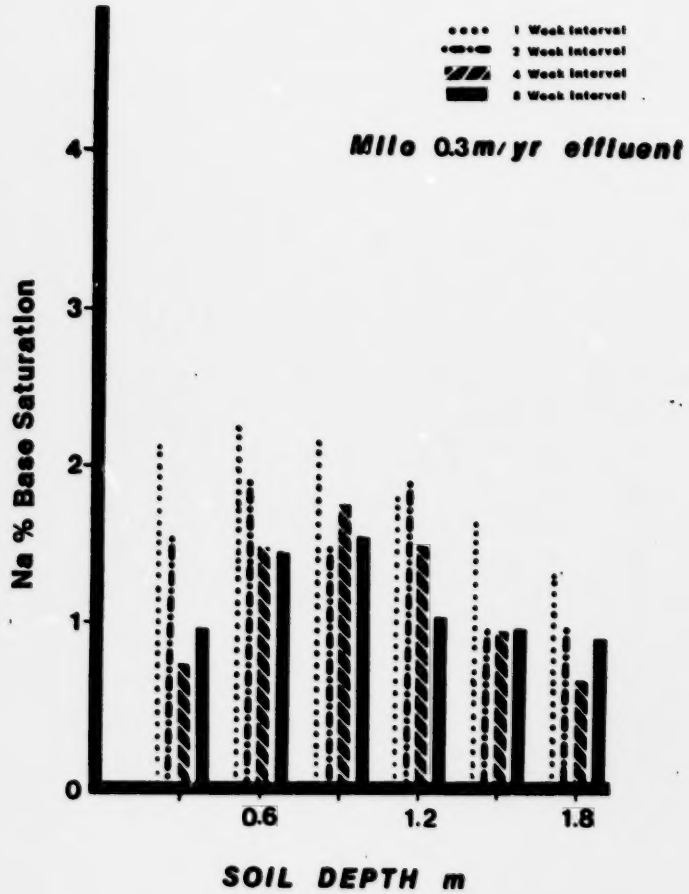


Figure 58. Na % Base Saturation at various depths over 4 frequencies of application and an annual effluent loading of 0.3 m on Grain Sorghum (Milo) test plots, Trial 17000

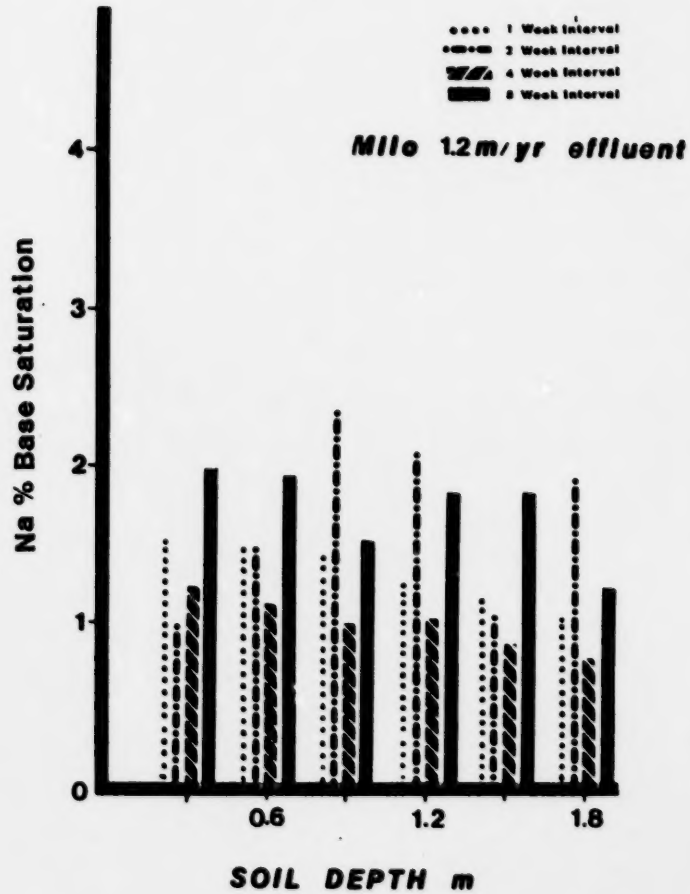


Figure 59. Na % Base Saturation at depths over 4 frequencies of application and an annual effluent loading of 1.2 m on Grain Sorghum (Milo) test plots, Trial 17000

sorghum and soybean plots are presented in Figures G.15, G.16 and Figures G.17, G.18, respectively. Generally, in each test plot K accumulated within the upper meter of the soil profile. The baseline soil samples prior to treatment contained higher K levels in the upper 61 cm than measured in samples obtained from treated plots. Fluctuations of up to 1000 ppm (4000 kg/ha) were seen between cores and at different zones from the same plot. These fluctuations could be due to several reasons:

1. A large portion of the potassium variations could be due to natural variation throughout the site
2. Leaching of K from the upper 61 cm may have also affected the K concentration
3. Some of the change in K concentration between baseline samples and fall samples can be explained by crop uptake

Approximately 50 to 160 kg K/ha were utilized by the grain sorghum. Soybeans consumed 28 to 45 kg K/ha.

The mass of chloride applied through irrigation to the test plots ranged from an average of 1030 kg Cl/ha (30 cm/yr) to 4170 kg/ha (122 cm/yr). Soybeans consumed 5 to 104 kg Cl/ha with an average crop utilization of 60 $\pm$ 32 kg Cl/ha. Chloride concentration in soils within the soybean test plots varied from 10 to 170 mg/kg soil. Soil chloride concentrations increased with increasing depth to 122 cm into the profile. As the hydraulic loading increased from 30 cm to 122 cm/yr, the concentration of chlorides within the lower 91 cm of the profile increased (Figures G.19 to G.21). The interval between irrigation events appeared to affect the soil chloride concentration in the lower 91 cm of the soybean plots irrigated with 30 cm once every four or eight weeks in 1982 (Figure G.19). Longer periods between irrigation events in plots watered with 30 cm of effluent per year produced higher chloride levels in soils at depths of 122, 152 and 183 cm than plots irrigated more frequently. Long dry periods between irrigation may have caused capillary rise of water from below the 183 cm depth and transported chlorides upward. Annual hydraulic loading of 122 cm applied to soybean plots at frequencies of one irrigation every two weeks and once every four weeks resulted in an increase in chloride mass in the lower 91 cm of the soil profile (Figure G.21). Once

the frequency of irrigation was reduced to one irrigation every eight weeks, the large quantity of water applied per irrigation reduced chloride levels throughout the entire profile.

Grain sorghum removed 217 to 391 kg of Cl/ha. As more chloride mass was applied to the test plots and available in the soil solution, crop consumption of chloride increased from an average of 256 kg/ha (30 cm/yr) to 297 kg/ha (61 cm/yr) and finally 323 kg/ha (122 cm/yr). With a chloride mass loading of 4172 kg/ha.yr (122 cm of effluent/yr) the soil chloride concentration increased in the top 30 cm and the lower 61 cm of soil (Figure G.22). Frequent irrigation of water (one per week) to sorghum plots having 122 cm of effluent applied in 1982 created a chloride lens (accumulation) at 61 cm in the soil profile. Conversely, with 30 cm of annual irrigation, a chloride lens was produced at a depth of 152 cm when the interval between irrigation events was eight weeks (Figure G.23).

Hydraulic Loading and Application Frequency Summary

Yield data indicated soybean production was highest with more frequent wastewater application (i.e., one irrigation/week and one irrigation/2 weeks); whereas, grain sorghum yields were significantly higher with longer periods between irrigation (1 irrigation/4 weeks and 1 irrigation/8 weeks). Soil moisture within the profile corresponded to the type of root system. Grain sorghum may have had a deeper, more fibrous root system; therefore, removed more water to a greater depth. Sodium increased in the plant at low irrigation rates. Leaching of Na resulted within the plots when greater quantities of water were applied per irrigation period. Consequently, less Na was available for the crop. Grain sorghum, with a deeper more extensive root system, was not affected by minor changes in loadings or frequencies of application, while a small shift of either of these factors on the soybean crop changed the availability of Na.

An annual hydraulic loading of 30 cm/yr symbiotic nitrogen fixation apparently provided inorganic nitrogen to the soybeans. Once the hydraulic loading was increased to 61 cm/yr, sufficient nitrogen mass was applied to soybeans to inhibit nitrogen fixation. In the soybean test plots inor-

ganic nitrogen leached through the 183 cm soil profile when 122 cm of effluent/yr was applied at intervals between irrigation greater than once per week. Similarly, nitrogen was leached from the 91 cm profile within the grain sorghum test plot irrigated with 122 cm/yr.

The ability of the crop to adapt to water stress conditions was a factor which influenced Na accumulation within the soil profile. Due to the shorter growing season in 1982, soybeans with possibly greater water requirements than sorghum and a more shallow root system, utilized water within the upper 61 cm of soil. Consequently, the greatest Na levels as a percent of base saturation was observed in the upper 61 cm of the soil. In addition, higher water application frequency appeared to increase ESP values in the upper soil profile.

Water utilized by grain sorghum caused an accumulation of Na at greater soil depths than soybeans. Upward migration of water due to capillary action during water stress periods (increased time intervals between irrigation) may have caused an increase in Na in the upper profile.

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APPENDIX A

Supplemental Material for Section 4, Research Approach

TABLE A-1. SOIL COMPOSITING PROTOCOL FOR 1982 AND 1983

Trial 14000

1983 - 0.9 mm (3 ft) cores

Early spring and late fall sampling periods

9 Treatments

4 Reps/treatment composited

3 Cores/rep composited

Trials 15000 and 16000

1982 and 1983 -

1.8 m (6 ft) cores

Early spring and late fall sampling periods

5 Treatments (crop and loading)

2 Reps/treatment composited

3 Cores/rep composited

Trial 17000

1982 - 0.91 (3 ft) cores

Early spring and late fall sampling periods

2 Crops

12 Treatments/crop

3 Reps/treatment composited

1 Core/rep

TABLE A-2. CROP SAMPLING PROTOCOL

Trial 14000

1983 - Yield

9 Treatments (hydraulic loading rate)

4 Reps/treatment

1 Sample/rep individual

- Analysis

9 Treatments (hydraulic loading)

1 Sample/rep

4 Reps/treatment composited

Trial 15000

1982 and 1983 - Yield

5 Treatments (crop and loading)

2 Reps/treatment

2 Samples/rep individual

- Analysis

5 Treatments (crop and loading)

2 Samples/rep composited

2 Reps/treatment composited

Trial 16000

1982 and 1983 - Alfalfa

- Yield

10 Treatments (hydraulic loading rate and water source)

2 Reps/treatments

2 Samples/rep/cutting individual

1982 - 1 Cutting 1983 - 5 Cuttings

- Analysis

10 Treatments (loading and water source)

2 Samples/rep/cutting composited

2 reps/treatment composited

1982 - 1 Cutting 1983 - 5 Cuttings

(continued)

TABLE A-2, continued

Bermuda

- Yield

  7 Treatments (hydraulic loading rate and water source)

  2 Reps/treatment

  2 Samples/rep/cutting individual

  1982 - 1 Cutting 1983 - 2 Cuttings

- Analysis

  7 Treatments (loading and water source)

  2 Samples/rep/cutting composited

  2 Reps/treatment composited

  1982 - 1 Cutting 1983 - 2 Cuttings

Trial 17000

1982 - Yield

  2 Crops

  12 Treatments/crop (hydraulic loading rate and frequency)

  3 Reps/treatment

  1 Sample/rep individual

- Analysis

  1 Crops

  12 Treatments/crop

  1 Sample/rep

  3 Reps/treatment composited

TABLE A.6. PRECISION AND ACCURACY DATA
WATER SAMPLE ANALYSES

Parameter	Range	Percent Accuracy	Precision
TOC mg/l	0-20	93-105	± 0.52
COD mg/l	0-100	90-122	± 3.19
CL^- mg/l	0-1000	98-104	± 1.25
SO_4^{2-} mg/l	0-1000	90-110	± 3.16
	0-300		
Total N mg/l	0-5	67-97	± 0.288
NO_2^-/NO_3^- mg/l	0-50	76-123	± 0.26
NH_3 mg/l	0-1	81-100	± 0.01
Total P mg/l	0-5	90-104	± 0.019
Ortho P mg/l	0-2.5	93-108	± 0.013
	0-1.00	90-100	± 0.48
Hydrolyzable P + Ortho P mg/l	0-1000	86-99	± 0.038
Conductivity mg/l	500-5000		± 10.83
pH mg/l	7.00-9.00		± 0.071
Alkalinity mg/l	100-800		± 3.60
	Bacteria (colonies/100 ml)		
Total Coliform - MF	0-100		± 1.5
	100-10,000		$\pm 4.0 \times 10^2$
	10,000-10^6		$\pm 2.2 \times 10^2$
Fecal Coliform - MF	0-100		± 2.88
	100-10,000		$\pm 3.47 \times 10^2$
Fecal Streptococci - MF	0-100		± 1.75
	100-10,000		$\pm 2.10 \times 10^2$
	Volatile Organics - PPB		
Benzene	0-2	71-103	± 0.10
Trichlorethylene	0-20	70-104	± 0.55

(continued)

Table A.6, continued

Parameter	Range	Percent Accuracy	Precision
Carbon tetrachloride	0-10	77-115	±4.90
Chloroform	0-20	76-113	±2.30
Chlorobenzene	0-20	84-97	±1.60
Ethylbenzene	0-20	88-112	±3.60
Tetrachloroethylene	0-20	83-115	±1.20
Tolulene	0-20	76-110	±1.0
Trichloroethane	0-20	75-108	±0.7
	Extractable Organics - PPB		
Acenaphthylene	0-100	61-88	±5.70
Anthracene	0-100	72-87	±2.70
Atrazine	0-100	71-93	±5.30
4-t-buthylphenol	0-100	76-88	±5.20
4-chloroaniline	0-100	45-67	±14.10
2-chlorophenol	0-100	45-86	±11.90
1-chlorotetradecane	0-100	70-86	±5.20
Dibutylphthalate	0-100	68-106	±6.00
2,3-dichloroaniline	0-100	57-83	±4.50
3,4-dichloroaniline	0-100	55-76	±8.90
2,4-dichlorophenol	0-100	64-93	±9.00
Diethylphthalate	0-100	70-93	±3.20
Heptadecane	0-100	79-99	±6.60
Methylhexadecanoate	0-100	78-97	±7.00
Methylheptadecanoate	0-100	79-100	±3.40
1-methylnaphthalene	0-100	60-83	±7.70
2-methylphenol	0-100	45-78	±7.80
4-methylphenol	0-100	42-75	±6.50

(continued)

Table A.6, continued

Parameter	Range	Percent Accuracy	Precision
Napthalene	0-100	58-84	± 8.70
Octadecane	0-100	69-97	± 2.50
Phenol	0-100	26-58	± 4.0
Propazene	0-100	63-90	± 1.90
α-terpineol	0-100	63-89	± 7.90
Dichlorobenzene-M	0-100	48-74	± 10.90
Dichlorobenzene-P	0-100	48-75	± 10.50
Dichlorobenzene-O	0-100	50-78	± 11.0
	Dissolved Metals - mg/l		
Arsenic	0-.10	93-120	± 0.003
Barium	0-.10	80-108	± 0.005
Calcium	10-100	75-120	± 2.33
Cadmium	0-.10	90-125	± 0.001
Cobalt	0-.10	85-115	± 0.0004
Chromium	0-.10	80-93	± 0.0008
Iron	0-10	96-110	± 0.007
Lead	0-.10	75-100	± 0.0003
Manganese	0-10	93-113	± 0.003
Molybdenum	0-.10	84-110	± 0.001
Nickel	0-.10	90-103	± 0.002
Potassium	10-100	71-115	± 1.31
Silver	0-.10	90-110	± 0.0001
Sodium	100-1000	89-116	±11.25
Thallium	0-.10	80-120	± 0.0007
Zinc	0-1.0	93-126	± 0.005
Copper	0-.10	82-112	± 0.005
Selenium	0-10	80-105	± 0.003
Magnesium	10-100	76-125	± 6.73

TABLE A.7. PRECISION AND ACCURACY DATA
SOIL SAMPLE ANALYSIS

Parameter	Range	Percent Accuracy	Precision
	Priority Organics (PPB)		
Chlorobenzene	0-10	±81-123	0.65
Benzene	0-10	±97	1.43
	0-100		2.73
Trichloroethylene	10-100	±85	1.2
Carbon tetrachloride	0-10	±96	0.80
	10-100	±70-96	1.0
	100-1000	±60	
Chloroform	0-10	±97	0.72
	10-100		4.2
Ethylbenzene	0-10	±109	1.64
Tetrachloroethylene	10-100	±95	17.93
	0-10		1.8
Toluene	0-10	±104	0.54
Trichloroethane	0-10	±95	
Acenaphthylene	0-10	±46-99	63.35
Anthracene	0-10	±57-66	44.40
4-t-butylphenol	0-10	±89-124	74.3
	10-100	±87	
4-chloroaniline	0-10	±25-46	27.94
2-chlorophenol	0-10	±52-102	44.78
1-chlorotetradecane	0-10	±60-114	79.37
	0-1000		205.
Dibutylphthalate	0-10	±67-191	400.63
	10-100	±74-141	
	100-1000	±61-101	
2,3-dichloroaniline	0-10	±48-108	59.16
3,4-dichloroaniline	0-10	±41-89	70.82

(continued)

Table A.7, continued

Parameter	Range	Percent Accuracy	Precision
Diethylphthalate/hexadecane	0-10	±56-194	
	10-100	±105-116	92.73
	100-1000	±35-194	60.15
	0-1000		165.47
Heptadecane	0-10	±51-124	72.86
	10-100	±87	
Methylhexadeconate	0-10	±61-154	102.67
Methylheptadecanoate	0-10	±62-152	101.67
	100-1000	±80	
1-methylnapthalene	0-10	±83-119	55.66
2-methylphenol	0-10	±54-114	89.41
4-methylphenol	0-10	±54-113	99.32
Napthalene	0-10	±49-99	100.73
Octadecane	0-10	±57-94	47.89
Phenol	0-10	±55-114	54.50
Propazine	0-10	±26-68	20.00
α-terpineol	0-10	±55-118	121.28
Dichlorobenzene M	0-10	±17-87	66.27
Dichlorobenzene P	0-10	±18-84	242.15
Dichlorobenzene O	0-10	±20-99	78.91
Diisooctylphthalate	0-10	±81-136	
	100-1000	±48-93	100.41
	0-1000		215.98
	0-10,000		110.31
	Bacteria (colonies/g dry wt)		
Total Coliform	2400		0
	5000		6.86 x 10
Fecal Coliform	2400		0
	5000		1.24 x 10

continued)

Table A.7,continued

Parameter	Range	Percent Accuracy	Precision
Fecal Streptococci	2400		0
	5000		2.18 x 10
Fungi	0-10		5.05 x 10
Actinomycetes	0-10		3.78 x 10
Total Place Count	<2400		0
	>2400		3.8 x 10
	Chemical mg/g		
Nitrite + Nitrate Nitrogen	0-0.05	±44-178	0.00047
	0-02000		0.00136
Organic C	1-10	±85-107	0.65
Alkalinity	0-0.50		0.03
Organic P	0-2.00		0.005
Chloride	0-0.20		4.35
Total P	0-2.00	±95-125	0.01
Available P	0-0.25	±36-118	0.00018
Inorganic P	0-0.5	±55-110	0.005
Sulfates	0-0.50	±45-120	0.006
NH_3-N	0-0.005	±96-113	0.00006
NO_3-N	0-0.05	±44-178	0.00047
	Physical		
% Clay - Texture	19.4-56.0		0.78
% Moisture - Lab	1.0-5.6		0.17
% Moisture - Field	10.2-20.8		0.15
Bulk Density g/cm	1.29-1.50		0.007
Particle Density	2.55-2.70		0.03
% Porosity	42.0-51.3		0.54
pH	7.01-8.58		0.04
Conductivity	90-1410		18.4

(continued)

Table A.7, continued

Parameter	Range	Percent Accuracy	Precision
µmhos/cm			0.02
TDS mg/g	0.14-0.93		
% Sand - Texture	21.8-67.8		0.69
% Silt - Texture	9.6-32.6		0.80
	Metals mg/kg		
Sodium	100-300	±54-103	18.6
Potassium	500-5000	±24-118	160.0
Magnesium	3000-5000	±50-120	118.7
Calcium	10,000-178,000	±44-120	1219.2
	Extractable		
Sodium	100-200	±16-111	14.0
Potassium	50-4000	±62-119	245.1
Magnesium	200-7000	±71-114	95.1
Calcium	5000-104,000	±57-130	8579.0
	Total		
Aluminum	6350-28,190	±36-146	1124.5
Arsenic	10.95-17.88	±27-96	1.03
Barium	84-340	±40-116	29.4
Calcium	1930-13,800	±84-170	626.4
Cadmium	0-10	±18-140	0.03
Iron	530-17,160	±40-140	178.5
Magnesium	1620-4110	±54-116	328.8
Manganese	160-276	±30-144	21.4
Potassium	3020-8780	±58-136	208.5
Silver	3.05-0.66	± 8-60	0.276
Sodium	178-648	±90-110	28.7
Thallium	<0.005-2.2	±64-118	0.495
Zinc	17-63	±62-137	3.7

(continued)

Table. A.7, continued

Parameter	Range	Percent Accuracy	Precision
Cobalt	0-10	±36-120	0.2055
Copper	0-100	±40-110	0.7305
Molybdnum	0-10	±48-112	0.1320
Nickel	0-100	±44-103	0.6025
Chromium	8.0-26.58	±60-122	2.95
Lead	0.71-6.94	± 4-113	2.95
Selenium	0.005	± 5-140	0.0471

TABLE A.8. ACCEPTABLE LIMITS FOR PRECISION, ACCURACY AND COMPLETENESS CROP SAMPLE ANALYSIS

Parameter	Range	Percent Accuracy	Precision	Percent Completeness
Cl^- mg/g	0.00-1.00	93-104	± 0.05	95
Sulfur mg/g	0.00-50.00	87-106	± 1.22	95
TKN mg/g	0.00-50.00	88-104	± 3.33	95
Total P mg/g	0.00-5.00	93-107	± 0.09	95
Oil mg/g	0.00-0.25	---	± 0.1	95
		Total Metals (mg/g)		
Aluminum	78-1334	84-110	± 85.	95
Arsenic	<0.5-1.0	86-102	± 0.	95
Barium	<1.0-26.0	77-120	± 0.8	95
Boron	93-189	87-120	± 3.1	95
Calcium	1730-17,000	120-130	± 91.	95
Cadmium	<0.05-0.30	94-120	± 0.3	95
Cobalt	<0.5-1.0	74-110	± 0.1	95
Chromium	<0.5-1.0	87-106	± 1.2	95
Copper	2.0-10.0	60-90	± 0.9	95
Iron	10-300	100-130	± 21.	95
Lead	<0.5-2.0	60-90	± 0.6	95
Magnesium	700-30,000	80-110	± 965.	95
Manganese	3.0-30.0	75-110	± 0.8	95
Molybdenum	<0.3-5.0	80-105	± 0.1	95
Nickel	<0.5-5.0	80-110	± 1.3	95
Potassium	600-12,000	90-105	± 349.	95
Selenium	<0.5-1.0	75-95	± 0.	95
Silver	<0.1-1.0	40-60	± 0.	95
Sodium	100-2,000	80-105	± 310.	95
Thallium	<0.5-2.0	85-105	± 0.5	95
Zinc	10-100	85-105	± 3.6	95

(continued)

Table A.8, continued

Parameter	Range	Percent Accuracy	Precision	Percent Completeness
		Bacteria (cfu/g)		
Total Coliforms-MPN	100-10	---	±179.	95
Fecal Coliforms-MPN	100-10	---	±87.	95
Fecal Strepto-cocci-MPN	100-10	---	±1000.	95

TABLE A.9. RESULTS U.S.E.P.A. PERFORMANCE EVALUATION STUDIES (EPA UNKNOWNS)

Element	Percent Results Acceptable	Percent Results Not Acceptable
	WP 581, 475, 580, 879, 1278, 478, 618 - June 1982	
Minerals	95	5
Nutrients	70	30
Organics	100	0
Metals	73	27
Priority Organics	91	9
	WP 006, 007 - August 1982	
Minerals	89	11
Nutrients	60	40
Organics	100	0
Metals	96	4
Priority Organics	100	0
	WP 009 - December 1982	
Minerals	95	5
Nutrients	90	10
Organics	100	0
Metals	93	7
Priority Organics	100	0
	WP 10 - June 1983	
Minerals	100 (84)*	0 (16)*
Nutrients	90 (70)*	10 (30)*
Organics	100 (86)*	0 (4)*
Metals	80 (82)*	20 (8)*
Priority Organics	100 (80)*	0 (20)*

(continued)

Table A.9, continued

Element	Percent Results Acceptable	Percent Results Not Acceptable
	WP 11 - December 1983	
Minerals	95	5
Nutrients	100	0
Organics	100	0
Metals	97	3
Priority Organics	88	12
	WP 12 - May 1984	
Minerals	100 (84)*	0 (16)*
Nutrients	100 (72)*	0 (28)*
Organics	100 (87)*	0 (13)*
Metals	67 (86)*	23 (14)*
Priority Organics	100 (86)*	0 (14)*
	Average acceptable and non-acceptable results for three year study period by element and overall average for study period	
Minerals	96	4
Nutrients	85	15
Organics	100	0
Metals	84	16
Priority Organics	96	4
Average	92	8

* Average results from non-EPA and non-State laboratories participating in U.S.E.P.A. Performance Evaluation Studies.

TABLE A.10. REPRODUCIBILITY IN SEPARATE LABORATORIES OF BACTERIAL INDICATOR DENSITIES IN WASTEWATER DURING BASELINE PERIOD (Camann et al, 1985)

Sample Date	Total Coliform (cfu/1200 ml)		Fecal Coliform (cfu/100 ml)	
	LCCIWR	UTSA	LCCIWR	UTSA
06/04/80	4.3×10^7	3.5×10^7	Not Done	8.7×10^6
07/29/80	5.0×10^7	3.8×10^7	2.5×10^7	7.2×10^6
11/04/80	3.2×10^7	1.4×10^7	1.5×10^7	8.8×10^6
01/20/81	1.0×10^7	6.0×10^6	2.0×10^6	1.5×10^6
02/17/81	1.5×10^7	1.1×10^7	4.6×10^6	3.4×10^6
03/10/81	2.7×10^7	1.2×10^7	4.5×10^6	1.6×10^6
03/24/81	1.8×10^7	1.6×10^7	4.0×10^6	8.3×10^6
04/21/81	4.0×10^7	5.2×10^7	5.3×10^6	5.9×10^6
05/05/81	2.9×10^7	Not done	5.9×10^6	8.6×10^6

TABLE A.11. REPRODUCIBILITY IN SEPARATE LABORATORIES OF FECAL COLIFORM DENSITIES IN WASTEWATER DURING 1982 AND 1983 (Camann et al 1985)

	Fecal Coliforms (colonies/ml)					
	Hancock Reservoir		Pipeline Effluent		Wilson Imhoff influent	
Sampling Date	UTSA[a]	LCCIWR	UTSA[a]	LCCIWR	UTA	LCCIWR
02/15,16/82			39	30		
02/15,16/82[b]			11,000	97,000		
03/01,02/82			5,600	30,000		
03/08,09/82			75,000	100,000		
03/15,16/82			79,000	180,000		
03/22,23/82			81,000	50,000		
03/29,30/82			55,000	52,000		
04/05,06/82			84,000	16,000		
04/19,20/82			110,000			
04/26,27/82			9,100			
06/14,15/82	520	940 (600)[c]	66,000	55,000		
06/29,30/82	60	200	68,000	60,000		
07/26,27/82	190		58,000			
08/09,10/82	390	370	35,000	20,000 (30,000)		
08/09,10/82	10	2 (1.7)	200	41		
09/13,14/82	350	700 (490)	65,000	34,000		
	UTA		UTA		UTA	
11/01,02/82	3.5	2.8	49,000	90,000	130,000[d]	90,000
12/13,14/82	730	180	31,000	40,000	110,000	100,000
02/16,17/82	15	10	59,000	4,000	14,000	40,000
03/07,08/83	4	1.7	23,000	18,000	150,000	180,000
03/21,22/83	150	90	6,100	20,000	76,000	45,000 (60,000)
04/04,05/83	100	44	20,000	14,000	150,000	51,000
04/18,19/83	440	200	18,000	10,000	130,000	90,000

(continued)

Table A.11, continued

Sampling Date	Hancock Reservoir UTSA	Hancock Reservoir LCCIWR	Pipeline Effluent UTSA	Pipeline Effluent LCCIWR	Wilson Imhoff influent UTA	Wilson Imhoff influent LCCIWR
05/16,17/83	---	---	---	---	350,000	60,000
06/27,28/83	300	160	59,000	39,000	260,000	54,000
07/11,12/83	150	5.5	53,000	27,000	370,000	180,000
07/25,26/83	3	1	48,000	40,000	240,000	13,000
08/08,09/83	110	50	120,000	40,000	310,000	90,000
08/22,23/83	30	1.7	90,000	20	230,000	20,000

a mean of triplicate assays
b trickling filter plant effluent
c parenthetical value, when given, is the result of a duplicate analysis
d samples taken as Imhoff tank effluent

TABLE A.12. REPRODUCIBILITY IN SEPARATE LABORATORIES OF FECAL STREPTOCOCCI DENSITIES IN WASTEWATER DURING 1982 and 1983 (Camann et al 1985)

	Fecal Streptococci (colonies/ml)			
	Hancock Reservoir		Pipeline Effluent	
Sampling Date	UTSA[a]	LCCIWR[b]	UTSA[a]	LCCIWR[b]
02/15,16/82			120	40
03/01,02/82			1,000	400
03/08,09/82			5,900	5,000
03/15,16/82			3,500	4,000
03/22,23/82			7,900	2,200
03/29,30/82			5,000	2,600
04/05,06/82			2,800	1,400
04/19,20/82			4,800	
04/26,27/82			1,800	
06/14,15/82	20.	12.8	1,000	1,890 (1500)
06/29,30/82	3.	10.	4,200	1,800
07/26,27/82	3.		2,300	
08/09,10/82	6.6	6.0	2,500	1,000 (2,000)
08/30,31/82	0.3	1.1	30	61
09/13,14/82	10.	100. (20)	3,500	5,100

a Mean of triplicate assays
b Parenthetical value, when given, is the result of a duplicate analysis

Plot Location Map for Trial 14000*

	417		415		413
407		409	410		412
406			403		
	314	315	316		318
	311		309	308	
301					306
218	217	216	215		
		209	210		
	205	204			201
		115	116		
	111		109	108	
101	103	104	105		

Plot Size = 4.1 m x 13.7 m (13.3 ft x 45 ft)

*Code - 1st digit is replicate number
Last two digits are plot number

Treatment Codes for Trial 14000 Plots

Trial 14000	Plot Numbers																
	01	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
Rep 1	6	2	10	18			8	16		12				4	14		
Rep 2	4		10	18				12	6					16	2	14	8
Rep 3	8				2		10	14		18			4	16	6		12
Rep 4		18			6	16		12	2		4	10		14		8	

Treatments for Trial 14000 Treatment Codes

Treatment Code	Hydraulic Loading
2	00 cm/yr (0 in/yr)
4	20 cm/yr (8 in/yr)
6	41 cm/yr (16 in/yr)
8	51 cm/yr (20 in/yr)
10	61 cm/yr (24 in/yr)
12	69 cm/yr (27 in/yr)
14	86 cm/yr (34 in/yr)
16	102 cm/yr (40 in/yr)
18	122 cm/yr (48 in/yr)

Figure A.1. Plot Map and Treatment Explanation for Trial 14000

Plot Location Map for Trial 15000 and 16000*

	Cotton						Long Season Grain Sorghum (Milo)					
15000		206		207	208	209	204		206			
	203				108	107	203	202	201	109		107
	101			104	105				103	104	105	
16000	212	211	210	209	208	207	212					207
		202	203	204	205	206	201	202	203		205	201
	112	111	110	109		107		111		109		107
	101	102	103	104		106			103	104	105	106
	Alfalfa						Bermuda					

Plot Size = 12.1m (40 ft) x 18.3m (60 ft)

*1st digit of plot code is rep number
2nd two digits of plot code are treatment code

Trial 15000 — Plot Number

	01	02	03	04	05	06	07	08	09	
Rep 1	3			1	2		5	4		Cotton
Rep 2			2		3		4	5	1	Cotton
Rep 1			5	4	3		1		2	Milo
Rep 2	1	2	3	4		5				Milo

Randomized treatment assignment to plots

Trial 16000 — Plot Number

	01	02	03	04	05	06	07	08	09	10	11	12	
Rep 1			7	6	4	1	5		3		2		Bermuda
Rep 2	5	1	7		4	6	3					2	Bermuda
Rep 1	2	3	7	1		6	4		5	12	11	10	Alfalfa
Rep 2		3	6	12	11	10	8	4	1	2	7	5	Alfalfa

Randomized treatment assignment to plots

Key:

Trial 15000

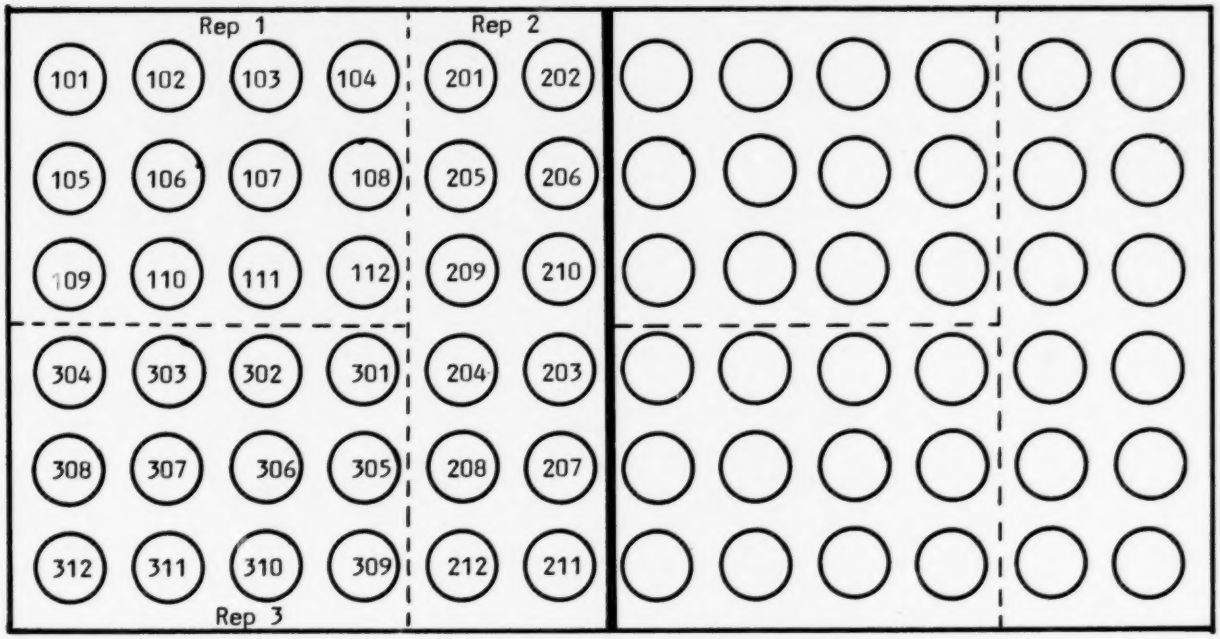
Treatment	Loading
1 =	122. cm/yr Effluent Loading
2 =	183. cm/yr Effluent Loading
3 =	229. cm/yr Effluent Loading
4 =	297. cm/yr Effluent Loading
5 =	000. cm/yr Effluent Loading

Trial 16000

Treatment	Loading	Treatment #	Loading
1 =	137. cm/yr Effluent Loading	7 =	000. cm/yr
2 =	198. cm/yr Effluent Loading	10 =	365. cm/yr Well Water Loading
3 =	259. cm/yr Effluent Loading	11 =	305. cm/yr Well Water Loading
4 =	305. cm/yr Effluent Loading	12 =	259. cm/yr Well Water Loading
5 =	365. cm/yr Effluent Loading		
6 =	434. cm/yr Effluent Loading		

Figure A.2. Designed Treatment for Trials 15000 and 16000

Trial 17000 Plot Map*



MILO **SOYBEANS**

Plot size is 4.57m (15 ft) Diameter with buffer spaces between application areas to minimize cross contamination from drift.

12 Treatments x 3 Reps x 2 Crops = 72 plots x 176.7 ft^2/plot = 0.29 Acres

For ease of application treatments were not randomized.

*Plot Code: 1st digit is rep number
Last two digits are treatment number

Figure A.3. Plot Map for Trail 17000

FIELD SAMPLING CODE

FOR

LCCIWR LUBBOCK LAND TREATMENT RESEARCH AND DEMONSTRATION PROJECT

	Sample Date	Site	Location	Identity Number	Sample Type	Sampling Method	Depth	LCCIWR Lab Sample No. (6 digits)
Symbols	Mo/Day/Year	G - Gray H - Hancock L - Lubbock W - Wilson	L - Lagoon W - Well R - Research P - Pivot D - Demonstration T - Trickling A - Activated Sludge S - Seep U - University I - Institute F - Force Main H - InHoff	Lagoon Number Well Number Research Plot No. Pivot Number Demo Number E# - Extraction Tray Lys. No. N = North S = South W = West E = East M = Middle 1 = Influent 2 = Effluent	W - Water S - Soil C - Crop	G - Grab C - Composite M - Mixed A - Alfalfa C - Cotton M - Milo W - Wheat O - Oats B - Bermuda S - Soybeans F - Sunflowers	Soil and Water Sample Depth Replication Number 0's - Surface Sample NO - Not Obtainable NO = (999) 000 - Surface Samples 001 Roots 002 Stalks, Stems, Leaves, Petioles, Burs 003 Seeds, Grain Only 004 Lint 005 Whole Head 006 Whole Plant except Roots	

Example: Well #6880 was sampled on the Gray Farm April 24, 1980. The depth to water was recorded as 51 ft and the water sample was given a lab number of 231, when it was brought into the lab for analysis.
SAMPLE CODE would be: 0424806W06880W6051000231

Note: All "Sample Identity Numbers", "Depths", and "Lab Numbers" not having 5, 3 or 6 digits respectively, need to be preceeded in 0's until the complete field of digits is represented.

Ex: Gray Well 6880 = 06880
Sample Depth 2 ft = 002
Lab Number 231 = 000231

Note: FOR SOILS: Cores composited over several feet depth would be listed with minimum and maximum depth.
Ex: Soil core composited from 4 ft to 6 ft depths = 046

Note: FOR SOILS AND CROPS: The first four digits of the sample identity number is derived by placing a 24 x 18 or 18 x 24 division grid over Gray and Hancock farm maps respectively with 0,0 being in the left lower corner. The 5th digit of the identity number represents the quadrant of that grid from which the sample was taken.

1	2
3	4

Figure A.4. Field Sampling Code

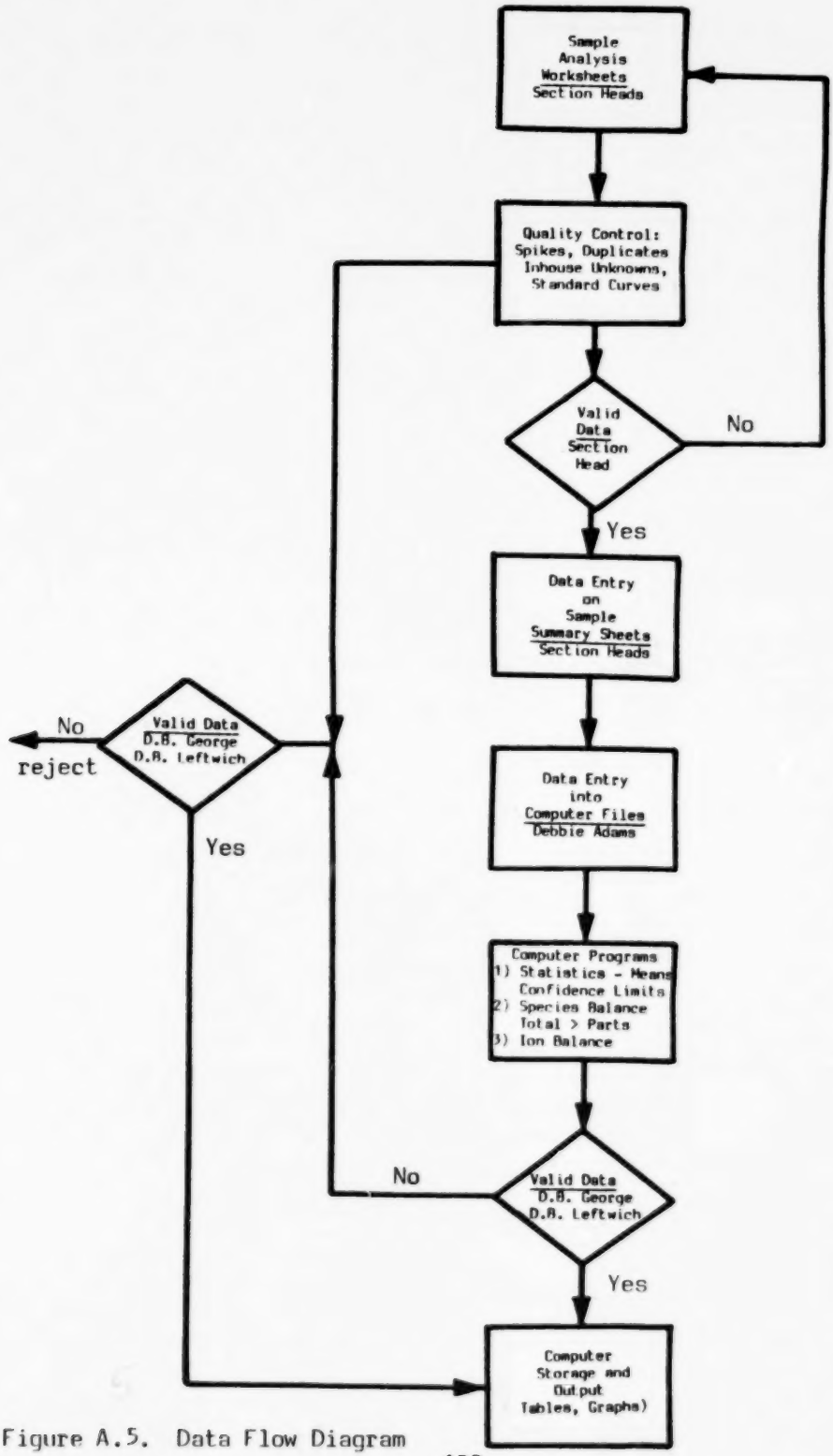


Figure A.5. Data Flow Diagram

APPENDIX B

Irrigation Water Quality

Table B.1 Water Quality Characteristics of Water Applied to Research Plots

ARITHMETIC MEANS
AND
STANDARD DEVIATIONS

SOURCE		ALKALINITY MG CACO3/L	CONDUCTIVITY	TDS MG/L	PH	CL MG/L	SO4 MG/L	TOTAL N MG N/L	NO2/NO3 MG N/L	NH3 MG N/L
Southeast Water Reclamation Plant Effluent	AV *	337.	2216.	1695.	7.54	468.	315.	38.59	0.29	25.95
	SD *	(34.)	(290.)	(537.)	(0.21)	(55.)	(43.)	(15.23)	(0.30)	(6.69)
	S *	<-0.07>	< 0.18>	< 3.00>	<-1.05>	<-1.62>	<-0.17>	< 1.40>	< 1.03>	< 0.42>
	MD *	382.	2130.	1635.	7.57	470.	311.	35.42	0.16	25.42
Effluent Entering Hancock Farm from Force Main	AV	382.	1969.	1190.	7.76	339.	208.	41.70	0.71	25.80
	SD	(54.)	(160.)	(107.)	(0.36)	(71.)	(46.)	(19.99)	(1.66)	(10.70)
	S	< 1.19>	<-1.45>	< 0.76>	< 1.43>	< 1.83>	<-0.05>	< 0.75>	< 3.57>	< 0.80>
	MD	383.	1975.	1180.	7.70	320.	208.	33.49	0.07	25.59
Freshwater Well	AV	276.	920.	716.	7.76	76.	98.	0.27	3.35	0.16
	SD	(12.)	(56.)	(271.)	(0.38)	(23.)	(38.)	(0.34)	(4.30)	(0.29)
	S	<-1.12>	<-0.32>	< 1.48>	< 0.05>	<-1.14>	< 1.18>	< 1.15>	< 1.10>	< 1.46>
	MD	281.	930.	611.	7.76	87.	82.	<0.10	1.58	0.04
Effluent from Reservoir	AV	299.	2093.	1241.	8.30	360.	200.	11.74	0.66	8.24
	SD	(30.)	(341.)	(56.)	(0.52)	(18.)	(52.)	(8.20)	(1.27)	(6.41)
	S	<-0.09>	< 2.53>	<-0.64>	<-0.01>	< 0.10>	<-2.66>	< 0.70>	< 2.95>	<-0.04>
	MD	303.	2085.	1246.	8.30	359.	215.	12.38	0.27	8.38

SOURCE		TOTAL P MG P/L	ORTHO P MG P/L	ORG. P MG P/L	COD MG/L	TOC MG/L
Southeast Water Reclamation Plant Effluent	AV	14.43	8.36	5.15	302.8	117.7
	SD	(4.27)	(2.03)	(4.20)	(135.6)	(45.1)
	S	< 1.47>	< 0.60>	< 0.56>	< 0.32>	< 0.69>
	MD	14.16	8.32	4.73	284.0	114.3
Effluent Entering Hancock Farm from Force Main	AV	11.82	8.43	1.60	325.6	64.1
	SD	(3.63)	(1.71)	(2.20)	(290.2)	(37.3)
	S	< 0.63>	< 0.23>	< 1.58>	< 1.84>	< 0.88>
	MD	11.13	8.29	0.49	237.5	51.9
Freshwater Well	AV	0.08	0.04	<0.01	6.0	1.5
	SD	(0.10)	(0.06)	(0.00)	(4.3)	(0.7)
	S	< 0.89>	< 1.43>	< 1.15>	< 0.68>	<-0.58>
	MD	0.02	<0.01	<0.01	5.0	1.7
Effluent from Reservoir	AV	6.31	4.85	0.61	75.1	20.8
	SD	(2.32)	(2.20)	(1.19)	(29.0)	(6.4)
	S	< 0.41>	<-0.17>	< 2.47>	< 0.09>	<-0.32>
	MD	5.92	5.17	0.19	68.3	20.8

Table B.1, continued

SOURCE		TOTAL COLIFORMS	FECAL COLIFORMS	FECAL STREP.
Southeast Water Reclamation Plant Effluent	AV	27326016.	8852272.	281659.
	SD	(16447465.)	(5933719.)	(592418.)
	S	< 0.45>	< 1.19>	< 3.78>
	MD	27000000.	6600000.	125500.
Effluent Entering Hancock Farm from Force Main	AV	22639168.	3576744.	243003.
	SD	(13669506.)	(3632328.)	(208804.)
	S	< 1.38>	< 2.24>	< 1.15>
	MD	23000000.	3000000.	210000.
Freshwater Well	AV	936.	>703.	38.
	SD	(1579.)	(1124.)	(30.)
	S	< 1.35>	< 0.70>	< -0.44>
	MD	150.	100.	42.
Effluent from Reservoir	AV	1054713.	109211.	151788.
	SD	(3457580.)	(433929.)	(670406.)
	S	< 4.12>	< 4.23>	< 4.13>
	MD	200000.	5000.	1000.

Table B.1, continued

METALS, DISSOLVED(MG/L)

SOURCE		AL	AS	BA	B	CA	CD	CO	CR	CU	FE	PB
Southeast Water Reclamation Plant Effluent	AV	1.277	0.009	0.198	1.278	54.7	0.002	0.006	0.059	0.081	0.731	0.018
	SD	(1.298)	(0.006)	(0.130)	(1.494)	(13.4)	(0.002)	(0.002)	(0.035)	(0.064)	(0.510)	(0.023)
	S	< 1.56>	< 1.62>	< 1.32>	< 2.33>	<-0.18>	< 2.25>	< 4.05>	< 0.09>	< 1.36>	< 0.89>	< 2.89>
	MD	0.640	<0.005	0.201	0.781	53.	0.000	<0.005	0.052	0.072	0.643	0.011
Effluent Entering Hancock Farm from Force Main	AV	0.828	0.006	0.078	0.220	58.4	0.012	<0.005	0.030	0.024	1.187	0.130
	SD	(0.532)	(0.002)	(0.067)	(0.270)	(7.0)	(0.046)	(0.000)	(0.030)	(0.026)	(0.698)	(0.468)
	S	< 0.17>	< 3.48>	< 0.17>	< 1.77>	< 0.76>	< 3.88>	< 1.00>	< 0.66>	< 1.32>	< 0.84>	< 3.87>
	MD	0.631	<0.005	0.088	<0.100	57.	0.000	<0.005	0.009	0.010	1.241	0.015
Freshwater Well	AV	0.173	0.006	0.038	0.851	55.6	0.000	<0.005	<0.005	<0.005	0.371	0.006
	SD	(0.124)	(0.002)	(0.002)	(0.0)	(27.2)	(0.0)	(0.0)	(0.0)	(0.0)	(0.235)	(0.001)
	S	< 0.84>	< 0.0 >	< 0.00>	< 0.0 >	< 1.09>	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	<-0.98>	< 0.0 >
	MD	0.131	0.006	0.038		44.	0.000	<0.005	<0.005	<0.005	0.456	0.006
Effluent from Reservoir	AV	0.844	0.006	0.032	0.106	65.2	0.000	<0.005	<0.005	0.011	1.097	<0.002
	SD	(1.113)	(0.003)	(0.062)	(0.244)	(3.2)	(0.000)	(0.0)	(0.000)	(0.017)	(1.064)	(0.001)
	S	< 1.30>	< 2.27>	< 2.27>	< 2.27>	< 0.99>	< 1.00>	< 0.0 >	< 2.27>	< 2.27>	< 0.93>	< 2.27>
	MD	0.279	<0.005	0.010	<0.100	64.	0.000	<0.005	<0.005	<0.005	0.615	<0.002

SOURCE		MG	MN	HG	MO	NI	K	SE	AG	NA	TL	ZN
Southeast Water Reclamation Plant Effluent	AV	36.8	0.056	0.000	0.007	0.062	21.3	0.015	0.006	378.4	<0.005	0.108
	SD	(7.6)	(0.025)	(0.000)	(0.004)	(0.065)	(7.3)	(0.018)	(0.003)	(131.7)	(0.001)	(0.100)
	S	< 0.32>	<-0.38>	< 0.61>	< 1.26>	< 2.19>	< 0.52>	< 2.58>	< 2.95>	< 1.13>	< 4.01>	< 1.34>
	MD	35.0	0.060	0.000	0.006	0.056	19.2	<0.005	<0.005	358.0	<0.005	0.076
Effluent Entering Hancock Farm from Force Main	AV	24.3	0.057	0.000	<0.003	0.048	19.5	<0.005	<0.005	318.6	<0.005	0.169
	SD	(1.9)	(0.029)	(0.000)	(0.000)	(0.056)	(7.5)	(0.000)	(0.001)	(50.9)	(0.000)	(0.087)
	S	< 0.73>	< 0.34>	< 1.00>	< 1.00>	< 1.04>	< 1.78>	< 1.00>	<-3.88>	< 0.08>	< 1.00>	< 0.86>
	MD	24.5	0.048	0.000	<0.003	0.006	18.1	<0.005	<0.005	317.5	<0.005	0.163
Freshwater Well	AV	40.7	0.013	0.0	0.0	<0.005	8.4	<0.005	0.003	105.8	<0.005	0.484
	SD	(8.9)	(0.013)	(0.0)	(0.0)	(0.0)	(2.0)	(0.0)	(0.003)	(23.1)	(0.0)	(0.543)
	S	< 1.07>	< 0.96>	< 0.0 >	< 0.0 >	< 0.0 >	<-1.05>	< 0.0 >	< 0.00>	< 0.98>	< 0.0 >	< 1.04>
	MD	37.6	0.009	0.0	0.0	<0.005	9.1	<0.005	0.003	97.0		0.262
Effluent from Reservoir	AV	27.4	0.057	0.000	<0.003	0.008	19.5	<0.005	<0.005	304.1	<0.005	0.102
	SD	(1.4)	(0.048)	(0.0)	(0.000)	(0.009)	(4.1)	(0.0)	(0.0)	(43.9)	(0.0)	(0.058)
	S	<-0.17>	< 1.26>	< 0.0 >	< 1.00>	< 2.27>	< 1.51>	< 0.0 >	< 0.0	<-0.49>	< 0.0 >	< 0.59>
	MD	27.2	0.045	0.000	<0.003	<0.005	19.3	<0.005	<0.005	308.0	<0.005	0.081

Table B.1, continued

METALS, TOTAL (MG/L)

SOURCE		AL	AS	BA	B	CA	CD	CO	CR	CU	FE	PB
Southeast Water Reclamation Plant Effluent	AV	0.650	0.034	0.216	0.822	67.0	<0.005	0.003	0.036	0.035	0.423	0.049
	SD	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	S	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >
	MD											
Effluent Entering Hancock Farm from Force Main	AV	0.091	0.006	0.192	0.034	47.5	0.001	0.004	0.067	0.057	0.821	0.036
	SD	(0.070)	(0.002)	(0.082)	(0.028)	(16.8)	(0.002)	(0.002)	(0.035)	(0.051)	(0.470)	(0.029)
	S	< 1.03>	< 0.83>	<-0.78>	< 1.36>	<-2.16>	< 1.76>	<-1.79>	< 0.31>	< 1.19>	<-0.02>	< 0.50>
	MD	0.086	<0.005	0.197	0.027	51.	0.000	<0.005	0.060	0.047	0.770	0.032
Freshwater Well	AV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SD	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	S	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >
	MD	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0	0.0	0.0
Effluent from Reservoir	AV	0.136	0.006	0.133	0.053	54.3	0.000	<0.005	0.006	0.051	0.774	0.008
	SD	(0.136)	(0.002)	(0.090)	(0.041)	(10.5)	(0.000)	(0.0)	(0.001)	(0.057)	(0.773)	(0.008)
	S	< 1.76>	< 0.75>	<-0.20>	< 0.18>	<-0.54>	< 1.00>	< 0.0 >	< 0.61>	< 1.45>	< 0.93>	< 0.96>
	MD	0.094	<0.005	0.157	0.038	54.	0.000	<0.005	0.006	0.033	0.360	0.005

SOURCE		MG	MN	MO	NO	NI	K	SE	AG	NA	TL	ZN
Southeast Water Reclamation Plant Effluent	AV	45.0	0.085	0.0	0.070	0.061	22.0	0.031	<0.005	384.0	<0.005	0.050
	SD	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	S	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >
	MD			0.0								
Effluent Entering Hancock Farm from Force Main	AV	27.0	0.025	0.000	<0.003	0.062	29.7	<0.005	0.004	225.3	<0.005	0.301
	SD	(9.1)	(0.012)	(0.0)	(0.002)	(0.058)	(10.7)	(0.0)	(0.004)	(81.5)	(0.0)	(0.527)
	S	<-2.71>	< 0.06>	< 0.0 >	< 1.57>	< 1.15>	<-2.38>	< 0.0 >	< 0.61>	<-2.00>	< 0.0 >	< 2.67>
	MD	29.3	0.024		<0.003	0.065	32.4	<0.005	0.003	235.0	<0.005	0.133
Freshwater Well	AV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SD	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	S	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >
	MD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Effluent from Reservoir	AV	28.4	0.040	0.000	<0.003	0.018	30.2	<0.005	0.004	255.7	<0.005	0.093
	SD	(5.1)	(0.019)	(0.0)	(0.000)	(0.020)	(7.8)	(0.0)	(0.001)	(55.5)	(0.0)	(0.108)
	S	<-2.61>	< 0.72>	< 0.0 >	< 1.00>	< 1.71>	<-1.68>	< 0.0 >	<-0.71>	<-1.66>	< 0.0 >	< 2.01>
	MD	30.2	0.038	0.000	<0.003	0.007	34.0	<0.005	<0.005	279.0	<0.005	0.066

Table B.1, continued

ORGANICS (PPB)

SOURCE		ACENAPHTHYLENE	ANTHRACENE/PHENATHRENE	ATRAZINE	BENZENE/TRICHLOROETHYLENE	BENZENEACETIC ACID	4-T-BUTYLPHENOL
Southeast Water Reclamation Plant Effluent	AV	4.9	6.1	10.9	1.1	16.6	5.1
	SD	(1.6)	(7.5)	(17.4)	(0.4)	(0.0)	(8.0)
	S	< 1.51>	< 2.44>	< 3.18>	< 2.80>	< 0.0 >	< 2.75>
	MD	5.00	<2.00	5.10	<1.00		2.00
Effluent Entering Hancock Farm from Force Main	AV	4.9	8.4	32.5	1.9	3.7	19.6
	SD	(6.0)	(12.8)	(36.9)	(1.5)	(2.6)	(69.3)
	S	< 4.31>	< 2.79>	< 2.09>	< 1.83>	< 0.00>	< 4.96>
	MD	4.55	3.20	18.25	<1.00	3.75	2.45
Freshwater Well	AV	3.0	<2.0	7.3	1.5	0.0	1.3
	SD	(1.7)	(0.0)	(4.6)	(0.9)	(0.0)	(0.6)
	S	< 0.71>	< 0.0 >	<-0.71>	< 0.71>	< 0.0 >	< 0.71>
	MD	<2.00	<2.00	<10.00	<1.00	0.0	<1.00
Effluent from Reservoir	AV	3.2	5.5	10.9	2.2	0.0	3.4
	SD	(1.5)	(6.9)	(7.9)	(2.4)	(0.0)	(3.2)
	S	< 0.37>	< 1.73>	< 0.70>	< 2.14>	< 0.0 >	< 2.69>
	MD	<2.00	<2.00	<10.00	<1.00	0.0	2.10

SOURCE		CARBON TETRACHLORIDE	4-CHLOROANILINE	CHLOROBENZENE	CHLOROFORM	2-CHLORO PHENOL	1-CHLOROTETRADECANE
Southeast Water Reclamation Plant Effluent	AV	8.0	29.0	1.1	<1.0	8.5	4.9
	SD	(9.3)	(36.7)	(0.3)	(0.1)	(6.9)	(4.4)
	S	< 3.72>	< 1.98>	< 4.01>	< 4.25>	< 0.51>	< 1.49>
	MD	5.00	<10.00	<1.00	<1.00	6.55	<2.00
Effluent Entering Hancock Farm from Force Main	AV	4.7	17.1	1.3	5.3	7.3	10.5
	SD	(4.6)	(38.9)	(1.9)	(6.3)	(16.6)	(9.1)
	S	< 2.89>	< 5.10>	< 5.20>	< 1.71>	< 4.35>	< 1.56>
	MD	4.70	<10.00	<1.00	2.70	2.00	8.65
Freshwater Well	AV	3.4	<10.0	<1.0	<1.0	1.3	<2.0
	SD	(1.5)	(0.0)	(0.0)	(0.0)	(0.6)	(0.0)
	S	< 0.31>	< 0.0 >	< 0.0 >	< 0.0 >	< 0.71>	< 0.0 >
	MD	3.10	<10.00	<1.00	<1.00	<1.00	<2.00
Effluent from Reservoir	AV	3.1	42.4	<1.0	1.9	3.5	6.5
	SD	(1.6)	(140.7)	(0.0)	(2.3)	(7.8)	(11.1)
	S	< 0.28>	< 4.10>	< 0.0 >	< 3.38>	< 3.95>	< 3.63>
	MD	<2.00	<10.00	<1.00	<1.00	1.30	2.60

Table B.1, continued

SOURCE		DIBUTYLPHATHALATE	2,3-DICHLOROANILINE	3,4-DICHLOROANILINE	DICHLOROBENZENE M	DICHLOROBENZENE P	DICHLOROBENZENE O
Southeast Water Reclamation Plant Effluent	AV	28.8	8.5	5.8	5.7	6.4	11.6
	SD	(60.3)	(6.1)	(7.2)	(6.9)	(7.0)	(12.0)
	S	< 3.24>	< 1.37>	< 2.28>	< 2.59>	< 2.15>	< 1.58>
	MD	8.80	6.15	<2.00	2.60	3.60	7.20
Effluent Entering Hancock Farm from Force Main	AV	103.9	13.3	8.2	11.2	7.3	14.0
	SD	(149.2)	(19.3)	(16.0)	(29.6)	(15.0)	(14.3)
	S	< 1.62>	< 2.59>	< 4.46>	< 5.02>	< 4.72>	< 1.56>
	MD	23.40	5.00	3.85	4.70	3.30	8.60
Freshwater Well	AV	0.3	3.0	<2.0	1.3	1.3	1.3
	SD	(2.0)	(1.7)	(0.0)	(0.6)	(0.6)	(0.6)
	S	<-0.52>	< 0.71>	< 0.0 >	< 0.71>	< 0.71>	< 0.71>
	MD	0.90	<2.00	<2.00	<1.00	<1.00	<1.00
Effluent from Reservoir	AV	36.0	3.5	3.2	4.2	3.3	4.9
	SD	(44.2)	(1.5)	(1.9)	(4.1)	(3.6)	(4.0)
	S	< 2.44>	<-0.21>	< 1.77>	< 2.34>	< 3.14>	< 1.15>
	MD	29.55	3.70	2.35	2.75	2.00	4.10

SOURCE		DICHLOROMETHANE	2,4-DICHLOROPHENOL	DIETHYLPHTHALATE	DIISOOCTYLPHTHALATE	DIOCTYLPHTHALATE	DODECANOIC ACID
Southeast Water Reclamation Plant Effluent	AV	72.2	7.7	6.5	63.1	7.3	0.0
	SD	(0.0)	(8.1)	(9.3)	(111.8)	(9.2)	(0.0)
	S	< 0.0 >	< 1.23>	< 3.03>	< 2.78>	< 1.32>	< 0.0 >
	MD		4.10	2.50	18.40	<2.00	0.0
Effluent Entering Hancock Farm from Force Main	AV	0.0	11.7	39.1	43.3	11.0	0.0
	SD	(0.0)	(14.8)	(69.3)	(144.2)	(37.1)	(0.0)
	S	< 0.0 >	< 2.78>	< 4.55>	< 3.57>	< 3.75>	< 0.0 >
	MD	0.0	7.45	28.40	<2.00	<2.00	0.0
Freshwater Well	AV	0.0	2.7	16.9	10.1	<2.0	0.0
	SD	(0.0)	(0.4)	(13.2)	(0.0)	(0.0)	(0.0)
	S	< 0.0 >	<-0.71>	<-0.55>	< 0.0 >	< 0.0 >	< 0.0 >
	MD	0.0	<3.00	21.40			0.0
Effluent from Reservoir	AV	5.5	6.7	15.9	<2.0	<2.0	0.0
	SD	(0.0)	(10.9)	(14.3)	(0.0)	(0.0)	(0.0)
	S	< 0.0 >	< 2.65>	< 1.01>	< 0.0 >	< 0.0 >	< 0.0 >
	MD		<3.00	13.00	<2.00	<2.00	0.0

Table B.1, continued

SOURCE		ETHYL BENZENE	HEPTADECANE	HEXADECANE	HEXADECANOIC ACID	METHYLHEPTADECANOATE	METHYLHEXADECANOATE
Southeast Water Reclamation Plant Effluent	AV	1.3	7.5	7.5	59.4	8.4	12.6
	SD	(1.0)	(7.7)	(8.3)	(33.0)	(11.1)	(24.2)
	S	< 3.30>	< 1.66>	< 1.46>	< 0.69>	< 1.66>	< 3.18>
	MD	1.00	3.90	3.20	42.50	<2.00	2.85
Effluent Entering Hancock Farm from Force Main	AV	1.7	14.3	<2.0	0.0	142.7	38.7
	SD	(1.5)	(14.8)	(0.0)	(0.0)	(690.0)	(84.4)
	S	< 4.37>	< 1.95>	< 0.0 >	< 0.0 >	< 5.19>	< 3.65>
	MD	1.00	10.95	<2.00	0.0	2.60	6.15
Freshwater Well	AV	1.7	1.3	<2.0	0.0	<2.0	<2.0
	SD	(0.6)	(0.6)	(0.0)	(0.0)	(0.0)	(0.0)
	S	<-0.71>	< 0.71>	< 0.0 >	< 0.0 >	< 0.0 >	< 0.0 >
	MD	2.00	<1.00		0.0	<2.00	<2.00
Effluent from Reservoir	AV	1.8	3.6	<2.0	13.9	10.5	16.9
	SD	(1.5)	(3.5)	(0.0)	(18.2)	(17.9)	(22.1)
	S	< 3.35>	< 1.55>	< 0.0 >	< 0.0 >	< 2.44>	< 2.09>
	MD	<2.00	2.00	<2.00	13.90	<2.00	7.15

SOURCE		1-METHYLNAPHTHALENE	2-METHYLPHENOL	4-METHYLPHENOL	NAPHTHALENE	4-NONYLPHENOL	OCTADECANE
Southeast Water Reclamation Plant Effluent	AV	6.8	6.1	8.7	3.1	0.0	4.3
	SD	(15.1)	(6.3)	(14.7)	(1.9)	(0.0)	(3.4)
	S	< 3.68>	< 1.78>	< 3.90>	< 1.66>	< 0.0 >	< 1.28>
	MD	2.00	2.25	5.00	2.00	0.0	<2.00
Effluent Entering Hancock Farm from Force Main	AV	6.4	5.3	16.1	14.2	12.1	18.6
	SD	(8.9)	(5.4)	(43.3)	(22.2)	(0.0)	(55.9)
	S	< 3.79>	< 1.91>	< 4.71>	< 3.01>	< 0.0 >	< 4.95>
	MD	2.90	3.30	5.00	7.85		5.80
Freshwater Well	AV	1.3	1.3	3.0	2.5	0.3	5.5
	SD	(0.6)	(0.6)	(1.7)	(0.4)	(0.4)	(3.1)
	S	< 0.71>	< 0.71>	< 0.71>	<-0.53>	< 0.0 >	<-0.65>
	MD	<1.00	<1.00	<2.00	2.60	0.0	6.90
Effluent from Reservoir	AV	3.2	1.9	3.4	5.3	26.1	7.8
	SD	(3.3)	(1.5)	(1.0)	(5.5)	(0.0)	(8.6)
	S	< 2.06>	< 3.21>	< 0.71>	< 2.38>	< 0.0 >	< 1.67>
	MD	2.00	2.00	2.25	2.50		2.85

Table B.1, continued

SOURCE		PHENOL	PROPAZINE	A-TERPINEOL	TETRACHLOROETHYLENE	TOLUENE	TRICHLOROETHANE	TRICHLOROETHYLENE
Southeast Water Reclamation Plant Effluent	AV	10.5	20.0	8.1	4.8	1.9	6.8	1.2
	SD	(8.4)	(54.0)	(16.2)	(12.6)	(2.4)	(8.1)	(0.8)
	S	< 1.71>	< 4.03>	< 3.10>	< 3.24>	< 2.66>	< 4.25>	< 4.01>
	MD	10.00	5.10	2.00	<1.00	<1.00	5.00	<1.00
Effluent Entering Hancock Farm from Force Main	AV	9.7	35.0	16.8	1.8	1.6	5.1	1.1
	SD	(11.5)	(61.9)	(27.4)	(1.9)	(2.1)	(1.1)	(0.3)
	S	< 3.93>	< 2.71>	< 1.89>	< 3.59>	< 3.72>	< 1.75>	< 3.06>
	MD	8.20	11.00	2.00	<1.00	<1.00	5.00	<1.00
Freshwater Well	AV	4.0	7.3	1.3	2.2	<1.0	<5.0	1.1
	SD	(5.2)	(4.6)	(0.6)	(2.0)	(0.0)	(0.0)	(0.2)
	S	< 0.71>	<-0.71>	< 0.71>	< 0.71>	< 0.0 >	< 0.0 >	< 0.0 >
	MD	<1.00	<10.00	<1.00	<1.00	<1.00		1.25
Effluent from Reservoir	AV	8.3	11.7	32.7	2.1	1.1	4.9	1.1
	SD	(7.2)	(13.9)	(113.3)	(1.0)	(0.5)	(0.3)	(0.3)
	S	< 1.51>	< 2.58>	< 3.93>	< 1.54>	< 4.13>	<-1.46>	< 2.39>
	MD	9.80	<10.00	2.00	<1.00	<1.00	5.00	<1.00

* AV = Arithmetic Average
SD = Standard Deviation
S = Skewness of Data
MD = Median Value

TABLE B.2. RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATERS (Pettygrove & Asano 1984)

Element	Recommended maximum Concentration[a] (mg/l)	Remarks
Al (aluminum)	5.0	Can cause non-productivity in acid soils (pH <5.5), but more alkaline soils at pH <5.5 will precipitate the ion and elimiate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to <0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd (cadmium)	0.01	Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended because of its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (chromium)	0.1	Not generally recognized as an essential growth element. Conservative limits recomended because of lack of knowledge on toxicity to plants.
Cu (copper)	0.2	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of reduced availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment, and buildings.

(continued)

Table B.2, continued

Element	Recommended maximum Concentration[a] (mg/l)	Remarks
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH >6.0 and in fine textured or organic soils.

[a] The maximum concentration is based on a water application rate that is consistent with good agricultural practices 1.22 ha.m/ha.yr (4 ac-ft/ac.yr) the water application rate exceeds this, the maximum concentration should be adjusted downward accordingly. No adjustment should be made for application rates of less than 4 acre-ft per year per acre. The values given are for waters used on a continuous basis at one site for the irrigation supply water.

Table B.2, continued

Element	Recommended maximum Concentration[a] (mg/l)	Remarks
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus and low levels (>0.075 mg/l). Acts similar to boron.
Mn (manganese)	0.2	Toxic to a number of crops at a few tenths mg to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.
Ni (nickel)	0.2	Toxic to a number of plants at 0.5 to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pb (lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element for animals but in very low concentrations.
Sn (tin)	---	Effectively excluded by plants; specific tolerance unknown.
Ti (titanium)	---	(See remark for tin)
W (tungsten)	---	(See remark for tin)
V (vanadium)	0.1	Toxic to many plants at relatively low concentrations.

(continued)

APPENDIX C

Crop Quality

TABLE C-1. CONCENTRATION OF SPECIFIC PARAMETERS IN GRAIN SORGHUM TISSUE

Crop Treatment	Year	Concentration in mg/g						Concentration in mg/kg													
		TKN		TP		Cl		Ca		Cd		Fe		Mn		K		Zn		Na	
		Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed
1	1982	27.2	16.5	.21	1.7	3.13	.95	5230	200	.11	.20	164	48	36.1	10.1	15,500	3100	11.4	17.6	52	44
	1983	3.6	10.2	.9	2.7	5.7	.56	4770	370	<.05	<.05	374	81	52.5	11.0	14,750	3250	14.0	21.9	74	43
2	1982	17.8	16.3	.57	1.77	4.1	.72	5430	215	.08	.17	490	48	27.8	10.7	12,350	2800	16.1	14.6	127	41
	1983	1.7	10.8	1.45	3.04	5.58	0.53	5050	340	<.05	<.05	367	42	50.1	10.5	14,900	3440	14.2	20.1	61	53
3	1982	13.7	18.1	.95	1.9	----	.7	4300	240	.06	.21	255	81	48.7	10.8	12,500	2850	12.5	15.8	63	53
	1983	3.0	10.8	1.81	3.4	6.98	.56	5000	340	<.05	<.05	409	15	63.2	8.8	15,640	3480	20.4	20.3	108	33
4	1982	16.8	16.2	1.01	2.31	4.95	.644	2450	380	.07	<.05	118	14	19.3	9	7,680	2720	11.4	15.4	34	49
	1983	3.6	8.2	2.53	3.28	5.34	0.40	4590	410	<.05	----	394	70	51.1	16.9	15,120	4050	19.4	23.9	96	19
5	1982	16.6	15.7	.18	1.74	11.0	.95	5680	220	.06	.075	195	59	53.	25.	19,000	2680	15.	15.	231	48
	1983	----	----	1.38	----	7.67	----	3480	----	----	----	557	----	43.	----	16,730	----	16.6	----	53	--

TABLE C-2. 1983 COTTON CHEMICAL CHARACTERISTICS, TRIALS 14000 AND 15000

Treatment	PARAMETER																			
	Concentration in mg/g						Concentration in mg/kg													
	TKN		TP		Cl		Ca		Cd		Fe		M		K		Zn		Na	
	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed
Trial 14000																				
2	14.3	30.8	1.55	3.25	----	2.03	12220	----	.07	----	103	----	17.6	----	18380	----	11.0	----	281	----
4	9.4	34.9	2.26	5.14	----	1.67	16070	1770	.20	.16	75	46	----	----	18400	10200	17.0	36.6	273	361
6	24.3	35.9	3.35	5.71	----	2.0	17810	1580	.14	.10	133	40	----	----	20729	11199	20.0	39.1	263	173
8	19.3	45.0	1.52	4.75	----	1.36	13140	1810	.11	.11	132	32	----	----	20440	8700	8.0	37.3	268	122
10	14.4	43.0	1.81	5.05	----	1.54	10860	1850	.17	.07	85	10	21.7	----	17430	9200	13.0	34.0	218	154
12	21.4	38.9	2.68	4.92	----	1.98	1537	2840	.30	.17	69	13	----	----	18200	9600	17.0	38.0	484	372
14	15.7	36.1	2.10	4.99	----	1.75	11990	1930	.07	.15	1344	32	22.6	----	17600	9500	14.0	39.3	236	188
16	15.1	36.2	1.98	4.96	----	1.81	11470	1780	.07	.28	87	33	18.7	----	16700	8200	12.0	32.9	298	166
18	19.8	29.3	3.69	5.21	----	3.37	17790	2270	.07	.10	98	9	29.7	----	19340	1396	15.0	37.0	530	120
Trial 15000																				
1	19.5	53.4	1.61	4.91	----	.836														
1	4.3	28.5	1.06	6.20	----	.35	6120	1720	----	----	82	104	10.3	----	17690	12700	7.1	36.3	379	133
2	17.3	52.4	1.87	4.30	----	.616														
2	8.3	34.2	.92	5.94	----	.35	6690	1650	----	<.05	60	39	10.3	----	16490	7800	7.4	32.4	489	364
3	19.1	39.7	1.88	4.99	----	9.08														
3	8.2	27.6	1.07	6.39	----	.37	7010	----	<.05	----	81	----	12.1	----	15030	----	8.4	----	452	----
4	21.4	37.7	2.12	5.18	----	1.21	11000	2150	.07	.16	31	40	6.3	5.4	16600	11500	13.	30.	535	77
4	3.5	25.4	1.55	6.29	----	.48	6890	1490	<.05	<.05	73	33	8.4	----	21820	8500	8.8	29.9	616	208
5	21.9	51.4	1.30	3.88	----	.16	10850	1695	.13	.22	122	51	7.9	7.35	15750	8600	28.7	27.6	445	78
5	10.3	42.6	.72	4.46	----	.34	8410	----	<.05	----	320	----	15.3	----	9430	----	8.7	----	781	----

TABLE C-3. 1982 AND 1983 ALFALFA CROP QUALITY, TRIAL 16000

Treatment	Year	Concentration in mg/g			Concentration in mg/kg							
		TKN	TP	CL^-	Ca	Cd	Fe	Mn	K	Zn	Na	% Protein
1	9/82	39.1	1.75	8.91	19,100	.09	277	34.7	23,000	20.9	744	24
1	9/83	44.8	2.39	14.22	13,970	<.05	181	35.3	20,500	20.7	897	28
2	9/82	38.9	2.0	8.0	19,700	.07	229	40.0	22,900	19.1	547	24
2	9/83	42.5	2.12	13.60	13,050	<.05	145	28.9	18,800	20.0	1089	27
3	9/82	39.5	1.73	7.2	21,000	.075	271	42.9	23,400	17.5	917	25
3	9/83	44.4	2.14	14.0	12,280	<.05	173	23.8	15,100	18.6	1169	28
4	8/82	39.6	2.20	11.1	19,800	.11	323	41.7	21,900	19.6	1235	25
4	8/83	42.5	2.57	14.45	13,420	<.05	116	28.0	18,810	20.1	1044	27
5	8/82	42.5	1.73	11.99	10,600	<.05	397	43.6	25,950	20.8	1040	27
5	8/83	42.1	2.46	13.41	12,020	<.05	121	22.5	15,800	21.5	1668	26
6	9/82	40.4	2.67	13.2	16,620	.11	326	43.0	25,850	23.7	2115	25
6	9/83	39.0	2.84	14.3	10,820	<.05	118	23.6	17,800	20.0	1584	24
7	9/82	40.4	1.65	3.8	23,050	.06	818	33.3	19,250	18.8	202.5	25
7	9/83	43.6	1.43	6.60	15,380	<.05	169	39.6	12,700	21.0	591	27
10	9/82	54.4	2.08	7.02	18,800	.06	268	34.1	28,900	19.0	536	34
10	9/83	49.4	1.57	6.91	15,040	<.05	139	36.6	16,300	20.6	514	31
11	9/82	40.1	1.95	6.38	18,800	.07	173	35.3	26,700	16.6	448	25
11	9/83	44.8	1.43	5.79	16,630	<.05	274	38.0	21,400	23.5	500	28
12	9/82	39.3	1.85	6.06	20,800	.06	193	36.4	26,200	34.7	624	25
12	9/83											

TABLE C-4. CHEMICAL CHARACTERISTICS OF BERMUDA WHOLE PLANT TISSUE

Treatment	Year	Concentration in mg/g			Concentration in mg/kg						
		TKN	TP	CL^-	Ca	Cd	Fe	Mn	K	Zn	Na
1	9/82	17.3	1.3	8.7	4670	.09	301.	83.4	18,100	14.3	481
1	9/83	12.0	1.18	8.05	4160	<.05	155	75.3	16,470	15.7	353
2	9/82	19.9	1.54	11.1	5125	.18	267	83.9	20,950	16.3	571
2	9/83	12.0	1.46	8.17	3760	<.05	176	78.1	17,250	17.8	429
3	9/82	20.6	3.45	10.3	4590	.13	251	81.4	23,650	17.5	612
3	9/83	13.1	1.46	6.99	3480	<.05	121	66.5	15,500	15.8	452
4	9/82	17.2	1.81	9.69	4690	.18	313	87.3	18,200	17.9	614
4	9/83	11.8	1.58	7.64	3770	<.05	121	76.5	15,420	14.2	993
5	9/82	18.9	1.56	11.6	4355	.12	350	81.0	19,100	14.7	547
5	9/83	9.7	1.54	5.41	3390	<.05	110	63.6	12,750	15.3	485
6	9.82	18.1	1.69	9.6	4310	.10	188	78.0	17,450	14.9	681
6	9/83	10.2	1.54	5.57	3210	<.05	124	71.7	17,710	15.7	518
7	9/82	14.4	0.6	9.7	5120	.08	67	39.5	16.500	11.5	150
7	9/83	13.1	0.77	8.37	4630	<.05	219	73.2	12,840	9.6	102

C.5. CHEMICAL CHARACTERISTICS OF GRAIN SORGHUM WHOLE PLANT TISSUE, TRIAL 17000

Treatment	TKN	TP	CL^-	Ca	Cd	Fe	Mn	K	Zn	Na
		(mg/g)					(mg/kg)			
1	11.9	0.75	2.63	3370.	0.05	57.	23.4	9700.	14.2	162.
2	20.5	0.63	3.16	4630.	0.10	390.	38.9	14,300.	17.3	160.
3	16.4	1.34	2.70	2970.	<0.05	297.	20.8	6400.	11.2	352.
4	6.8	0.54	2.935	4510.	0.07	125.	27.8	16,200.	9.2	399.
5	18.4	1.01	2.680	3290.	0.05	65.	27.5	9300.	14.6	128.
6	11.8	0.62	3.331	5250.	0.11	524.	49.8	11,400.	20.3	282.
7	25.5	0.63	2.558	3750.	0.08	106.	25.8	11,300.	15.5	241.
8	13.9	0.84	3.282	3240.	0.07	120.	19.2	12,300.	10.7	139.
9	13.9	0.92	3.924	4680.	0.53	234.	37.6	16,100.	13.5	216.
10	17.9	0.88	3.292	2050.	0.06	33.	30.4	5000.	12.9	104.
11	18.9	0.97	2.344	3430.	0.07	91.	32.7	10,400	15.0	152.
12	15.4	1.05	2.741	3680.	0.05	82.	22.5	12,200	18.6	143.

TABLE C-6. CHEMICAL CHARACTERISTICS OF SOYBEAN WHOLE PLANT TISSUE

	Concentration in mg/g						Concentration in mg/kg													
	TKN		TP		Cl^-		Ca		Cd		Fe		MN		K		Zn		Na	
Treatment	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed
1	12.8	79.4	0.60	6.77	1.292	0.11	17,000.	2250.	<0.05	0.08	303.	192.	27.7	21.1	14,300.	16,400.	4.7	37.0	146.	24.
2	11.3	79.9	0.64	6.18	0.217	0.180	15,600.	2130.	<0.05	0.06	301.	85.	29.9	17.1	13,300.	13,300.	13.7	37.9	142.	318.
3	15.4	100.6	0.97	6.28	0.400	0.182	17,300.	2120.	<0.05	<0.05	482.	138.	30.0	15.9	11,700.	17,800.	17.3	35.3	180.	276.
4	12.8	107.6	0.74	6.53	4.077	1.835	15,800.	2150.	<0.05	<0.05	202.	140.	8.45	23.3	14,200.	17,200.	11.9	41.6	140.	43.
5	23.2	100.6	0.80	4.93	4.363	1.716	14,900.	2160.	<0.05	0.06	579.	430.	21.3	37.2	13,200.	14,300.	14.9	45.2	258.	56.
6	25.0	98.5	0.75	5.22	4.470	0.153	15,400.	2280.	<0.05	0.06	224.	233.	19.8	26.3	13,000.	17,400.	9.8	38.8	394.	116.
7	22.7	104.6	0.72	5.35	4.939	0.173	15,900.	1870.	<0.05	0.09	299.	128.	18.8	22.3	13,100.	13,400.	9.4	35.3	202.	37.
8	18.4	107.6	0.75	4.36	5.198	0.153	13,800.	1980.	0.08	0.15	144.	97.	20.6	24.3	12,400.	13,200.	9.1	37.8	223.	58.
9	22.4	101.6	0.80	5.52	4.403	0.204	14,600.	1960.	0.08	0.17	182.	82.	21.3	22.9	13,000.	12,600.	14.1	34.7	185.	41.
10	24.7	101.6	0.89	5.52	5.567	0.214	13,400.	2100.	0.07	0.07	134.	26.	14.0	23.4	10,000.	14,200.	12.5	38.3	167.	46.
11	24.5	104.6	1.19	5.92	5.096	0.194	14,500.	2090.	0.08	0.07	94.	106.	17.9	24.4	17,200.	19,600.	9.4	39.7	176.	53.
12	26.0	110.6	1.09	5.65	6.217	0.204	14,000.	1930.	0.10	0.08	194.	109.	17.8	17.7	16,500.	18,600.	11.2	33.6	178.	68.

TABLE C.7. NUTRIENT RATIOS IN GRAIN SORGHUM (MILO) TISSUE, TRIAL 15000

Sample Number	Year	K/N Stalk	K/N Seed	K/N Stalk	K/N Seed	K/N Stalk	K/N Seed
1	1982	0.57	0.19	73.8	1.82	18.4	96.6
	1983	4.10	0.32	16.39	1.20	64.3	123.3
2	1982	0.70	0.17	21.67	1.58	35.4	121.2
	1983	8.76	0.32	10.28	1.13	102.1	151.2
3	1982	0.91	0.16	13.16	1.50	76.0	120.3
	1983	5.21	0.32	8.64	1.02	88.7	167.5
4	1982	0.46	0.17	7.60	1.18	88.6	150.
	1983	4.15	0.50	5.98	1.23	130.4	137.2
5	1982	1.14	0.17	105.6	1.54	12.	116.

TABLE C.8. NUTRIENT RATIOS FOR 1982 AND 1983 ALFALFA PLANT TISSUE, TRIAL 16000

Treatment	Year	N/P	K/P	K/N	P/Zn
1	1982	22.3	13.1	0.59	83.7
1	1983	18.7	8.6	0.46	115.5
2	1982	19.4	11.4	0.59	104.7
2	1983	20.0	8.9	0.44	106.0
3	1982	22.8	13.5	0.59	98.9
3	1983	20.7	7.1	0.34	115.1
4	1982	18.0	10.0	0.55	112.2
4	1983	16.5	7.3	0.44	127.9
5	1982	24.6	15.0	0.61	83.2
5	1983	17.1	6.4	0.38	114.4
6	1982	15.1	9.7	0.64	112.7
6	1983	13.7	6.3	0.46	142.0
7	1982	24.5	11.7	0.48	87.8
7	1983	30.5	8.9	0.29	68.1
10	1982	26.2	13.9	0.53	109.5
10	1983	31.5	10.4	0.33	76.2
11	1982	20.5	13.7	0.66	117.5
11	1983	31.3	15.0	0.48	60.9
12	1982	21.2	14.2	0.67	53.3
12	1983				
*Normal Ratios		10.0	18.0	0.83	120.0

*Monson

APPENDIX D

Parameter and Coefficient Values for Nitrogen Mass Balance Model

TABLE D-1. INPUT PARAMETERS AND COEFFICIENTS FOR N MASS BALANCE ON GRAIN SORGHUM TEST PLOTS, TRIAL 15000

Parameter	Symbol	Annual Hydraulic Loading, Q_{ir}, (m)				
		0.0	1.37	1.83	2.13	2.82
1982 Inorganic nitrogen mass in 183 cm soil profile (kg-N/ha)	$N_{ior}{}^{t-1}$	151.9	90.6	128.7	49.4	66.4
1982 Organic nitrogen mass in 183 cm soil profile (kg-N/ha)	$N_{or}\|^{t-1}$	6731	6778	687	569	7495
Nitrogen concentration in irrigation water (mg-N/l)	C_{ir}	18.32	18.32	18.32	18.3	18.3
Amount of precipitation in 1983 (cm)	Q_p	45.72	45.72	45.72	45.72	45.72
*Assumed nitrogen concentration in precipitation (mg-N/l)	C_p	1.2	1.2	1.2	1.2	1.
Fraction of nitrogen applied by irrigation	e	0.95	0.95	0.95	0.95	0.95
Runoff coefficient	a	0.0	0.0	0.0	0.0	0.0
Mineralization rate constant (yr-1)	k_m3	0.0052	0.0052	0.052	0.0052	0.0052
Denitrification coefficient	C	0.10	0.30	0.30	0.30	0.30

*Mehren et al 1981

TABLE D-2. PARAMETER AND COEFFICIENT VALUES FOR NITROGEN MASS BALANCE ON TEST PLOTS, TRIALS 14000 and 15000 *

Parameter	Symbol	Trial 14000		Trial 15000				
		Annual Hydraulic Loading, Q_{ir}(m)						
		0.0 to 51	0.61 to 1.22	0.0 cm	1.22 cm	1.83 cm	2.29 cm	2.97 cm
Spring 1983 Inorganic nitrogen mass in soil profile (kg-N/ha)	$N_{ior}\|t-1$	75.19	75.19	212.6	142.8	129.3	44.9	31.1
Spring 1983 Organic nitrogen mass in soil profile (kg-N/ha)	$N_{or}\|t-1$	5369.	5369.	5927	9991.	8169.	7279.	7850.
Nitrogen concentration in irrigation water (mg-N/l)	C_{ir}	18.40	18.40	18.40	18.40	18.40	18.40	18.40
Amount of precipitation in 1983 (cm)	Q_p	45.72	45.72	45.72	45.72	45.72	45.72	45.72
**Assumed nitrogen concentration in precipitation (mg-N/l)	C_p	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Fraction of nitrogen applied by irrigation	e	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Runoff coefficient	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mineralization rate constant (yr-1)	k_m3	0.03	0.03	0.01	0.03	0.03	0.03	0.03
Denitrification coefficient	C	0.10	0.30	0.10	0.30	0.30	0.30	0.30

* 91 cm soil cores collected from Trail 14000 plots test and 183 cm cores collected from Trial 15000 test plots
** Mahren et al 1981

TABLE D-3. PARAMETER AND COEFFICIENT VALUES FOR NITROGEN MASS BALANCE ON ALFALFA TEST PLOTS, TRIAL 16000

Parameter	Symbol	Annual Hydraulic Loadings, Q_{ir}, (m)									
		0.0	1.37	1.98	2.59	3.05	3.65	4.34	3.65	3.05	2.59
February 1983 Inorganic nitrogen mass in 183 cm soil profile (kg-N/ha)	$N_{ior}\|t-1$	118.1	42.9	149.8	112.4	73.9	39.0	22.2	7.7	21.0	10.2
February 1983 Organic nitrogen mass in 183 cm soil profile (kg-N/ha)	$N_{or}\|t-1$	5237.	8309.	7454.	5558.	6394.	7632.	10153.	7081.	7497.	5456.
Nitrogen concentration in irrigation water (mg-N/l)	C_{ir}		18.40	18.40	18.40	18.40	18.40	18.40			
Amount of precipitation in 1983 (cm)	Q_p	45.72	45.72	45.72	45.72	45.72	45.72	45.72	45.72	45.72	45.72
*Assumed nitrogen concentration in precipitation (mg-N/ha)	C_p	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Fraction of nitrogen applied by Irrigation	e	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Runoff coefficient	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mineralization rate constant (yr-1)	k_{m3}	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Denitrification coefficient	C	0.10	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30

TABLE D-4. PARAMETER AND COEFFICIENT VALUES FOR NITROGEN MASS BALANCE ON BERMUDA TEST PLOTS, TRIAL 16000

	Symbol	Units	Annual Hydraulic Loading, Q_{ir} (m)						
			0.0	1.52	1.98	2.59	3.05	3.50	3.96
February 1983 Inorganic nitrogen mass in 183 cm soil profile	$N_{ior}\|t-1$	kg-N/ha	98.4	78.6	84.0	106.3	53.9	56.6	41.6
February 1983 Organic nitrogen mass in 183 cm soil profile	$N_{or}\|t-1$	kg-N/ha	9460.	6478.	7157.	8124.	7964.	8571.	9107.
Nitrogen concentration in irrigation water	C_{ir}	mg-N/l	18.4	18.4	18.4	18.4	18.4	18.4	18.4
Amount of precipitation in 1983	Q_p	cm	45.72	45.72	45.72	45.72	45.72	45.72	45.72
Assumed nitrogen concentration in precipitation	C_p	mg-N/l	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Fraction of nitrogen applied by irrigation	e		0.95	0.95	0.95	0.95	0.95	0.95	0.95
Runoff coefficient	a		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mineralization rate constant	K_{m3}	yr^{-1}	0.01	0.03	0.03	0.03	0.03	0.03	0.03
Denitrification coefficient	C		0.10	0.30	0.30	0.30	0.30	0.30	0.30

TABLE D-5. PARAMETER AND COEFFICIENT VALUES FOR NITROGEN MASS BALANCE ON GRAIN SORGHUM TEST PLOTS, TRIAL 17000

Parameter	Symbol	Annual Hydraulic Loading Q_{ir}, (m)											
		0.30				0.61				1.22			
		Application Frequency											
		1/wk	1/2-wk	1/4-wk	1/8-wk	1/wk	1/2-wk	1/4-wk	1/8-wk	1/wk	1/2-wk	1/4-wk	1/8-wk
Inorganic Nitrogen Mass in 91 cm soil Profile, July 1982	$N_{ior}\|t-1$	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
Organic Nitrogen Mass in 91 cm soil Profile, July 1982	$N_{ior}\|t-1$	5538.	5538.	5538.	5538.	5538.	5538.	5538.	5538.	5538.	5538.	5538.	5538.
Nitrogen Concentration in Irrigation Water	C_{ir}	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91
Amount of Precipitation in 1982	Q_p	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
*Assumed Nitrogen Concentration in Precipitation	C_p	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Fraction of Nitrogen Applied by Irrigation	a	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Runoff Coefficient	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mineralization Rate Constant	K_{m3}	0.0052	0.015	0.01	0.0052	0.0052	0.0052	0.02	0.0052	0.01	0.01	0.01	0.01
Denitrification Coefficient	c	0.10	0.10	0.10	0.10	0.20	0.20	0.10	0.20	0.20	0.20	0.20	0.20

* Mehren et al 1981

TABLE D-6. PARAMETER AND COEFFICIENT VALUES FOR NITROGEN MASS BALANCE ON SOYBEAN TEST PLOTS, TRIAL 17000

Parameter	Symbol	Annual Hydraulic Loading Q_{ir}, (m)											
		0.30				0.61				1.22			
		Application Frequency											
		1/wk	1/2-wk	1/4-wk	1/8-wk	1/wk	1/2-wk	1/4-wk	1/8-wk	1/wk	1/2-wk	1/4-wk	1/8-wk
Inorganic Nitrogen Mass in 91 cm soil Profile, July 1982	$N_{ior}\|t-1$	62.7	62.7	62.7	62.7	62.7	62.7	62.7	62.7	62.7	62.7	62.7	62.7
Organic Nitrogen Mass in 91 cm soil Profile, July 1982	$N_{ior}\|t-1$	4210.	4210.	4210.	4210.	4210.	4210.	4210.	4210.	4210.	4210.	4210.	4210.
Nitrogen Concentration in Irrigation Water	C_{ir}	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91
Amount of Precipitation in 1982	Q_p	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
*Assumed Nitrogen Concentration in Precipitation	C_p	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Fraction of Nitrogen Applied by Irrigation	a	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Runoff Coefficient	a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mineralization Rate Constant	K_{m3}	0.0052	0.01	0.01	0.01	0.0052	0.0052	0.0052	0.0052	0.01	0.01	0.01	0.01
Denitrification Coefficient	c	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.20	0.20

* Mahren et al 1981

TABLE D.7. NITROGEN UPTAKE BY GRAIN SORGHUM

Year	Treatment Numbers	Hydraulic Loading (m/yr)	N Crop Uptake* (kg/yr)
1982	1	0.61	94.8
	2	0.61	104.4
	3	0.91	116.9
	4	1.06	111.0
	5	0.00	77.4
1983	1	1.37	68.7
	2	1.83	66.0
	3	2.13	76.2
	4	2.82	68.0
	5	0.00	30.0*

*Estimation based on yield and typical TKN values presented in A & L Feed Manual

TABLE D.8. NITROGEN REMOVAL BY COTTON

Trial	Treatment	Annual Hydraulic Loading (cm)	N Mass Applied (kg-N/ha)	N Uptake by Crop (kg-N/ha)
14000	4	20	35.0	44.3
	6	41	71.7	29.3
	8	51	89.1	91.5
	10	61	106.6	62.0
	12	69	120.6	68.0
	14	86	150.3	69.8
	16	102	178.3	32.8
	18	122	213.3	32.8
15000	1	122	213.3	103.5
	2	183	319.9	157.2
	3	229	400.3	115.9
	4	297	519.2	103.7

TABLE D.9. ORGANIC N MASS PRESENT IN SOIL CORES OBTAINED FROM COTTON TEST PLOTS
TRIALS 14000 and 15000

Trial	Treat-ment	Annual Hydraulic Loading (cm)	Total N Mass (kg/ha)		Organic N Mass (kg/ha)		Percent of Total N	
			Spring 1983	Winter 1984	Spring 1983	Winter 1984	Spring 1983	Winter 1984
*14000	2	0.	5950.	5820.	5370.	5560.	90.	95.
	4	20.		5730.		5470.		95.
	6	41.		5280.		5050.		95.
	8	51.		2930.		2700.		92.
	10	61.		3810.		3720.		98.
	12	69.		3060.		2960.		97.
	14	86.		3500.		3380.		97.
	16	102.		3700.		3600.		97.
	18	122.		3030.		2960.		98.
**15000	1	122.	10,100.	8090.	9990.	8060.	99.	100.
	2	183.	8300.	6180.	8170.	6140.	98.	99.
	3	229.	7320.	6230.	7280.	6170.	99.	99.
	4	297.	8050.	6900.	7850.	6850.	98.	99.
	5	0.	6140.	7720	5930.	7500.	97.	97.

* cores to 91 cm depth
** cores to 183 cm depth

TABLE D.10. NITROGEN REMOVAL BY ALFALFA TRIAL 16000

Treat-ment	Annual Hydraulic Loading (cm) 1982	1983	September 1982 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	May 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	June 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	August 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)
1	23.	137.	39.1	1700	66.	39.7	3520	140.	36.0	3390	122.	37.6	3830	106.
2	46.	198.	38.9	1260	49.	35.9	3820	138.	39.7	4730	188.	36.8	3380	124.
3	76.	259.	39.5	1600	63.	33.2	3610	120.	34.4	4620	159.	39.9	3550	140.
4	107.	305.	39.4	2350	93.	27.6	3730	103.	38.7	4690	181.	37.4	3260	122.
5	137.	365.	42.5	1700	72.	33.2	3680	122.	33.8	5800	196.	43.7	4150	181.
6	137.	434.	40.4	1650	67.	33.2	4340	144.	52.0	5460	287.	42.7	3030	168.
7	0.	0.	40.4	650	26.	36.9	2270	84.	34.7	2210	77.	37.3	890	33.
*10	137.	365.	54.4	1550	84.	35.0	2630	92.	38.0	2700	102.	29.6	2700	80.
*11	107.	305.	40.1	1750	70.	32.2	3500	113.	36.9	2700	100.	44.5	2240	100.
*12	76.	259.	39.3	1250	49.	33.	2600	86.	45.1	2100	95.	37.6	1610	60.

Treat-ment	Annual Hydraulic Loading (cm) 1982	1983	September 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	November 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	TOTAL 1982	1983
1	23.	137.	44.8	2550	114.	25.5	2830	61.	66.	543.
2	46.	198.	42.5	3130	133.	26.2	2260	59.	49.	642.
3	76.	259.	44.4	3620	161.	22.7	2080	47.	63.	626.
4	107.	305.	47.5	3790	161.	18.8	2880	54.	93.	621.
5	137.	365.	42.1	4530	191.	19.8	2920	58.	72.	747.
6	137.	434.	39.0	4380	171.	18.6	3060	57.	67.	824.
7	0.	0.	43.6	----	0.	30.9	1550	48.	26.	242.
*10	137.	365.	49.4	1980	98.	18.2	2120	39.	84.	411.
*11	107.	305.	44.8	1810	81.	21.0	2020	43.	70.	435.
*12	76.	259.	40.0	2440	98.	21.6	1350	29.	49.	368.

*Irrigated with Ground Water

TABLE D.11. SOIL NITROGEN FORMS IN BERMUDA TEST PLOTS

Treatment	Annual Hydraulic Loading (cm)	NH_3 (kg/ha)		Organic N (kg/ha)		NO_2/NO_3 (kg/ha)		Total N (kg/ha)	
		Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983
1	152.	7.7	10.7	6480.	7580.	70.9	18.5	6560.	7610.
2	198.	12.3	9.6	7160.	6990.	71.7	16.9	7240.	7020.
3	259.	69.0	5.3	8120.	7420.	37.3	19.0	8230.	7440.
4	305.	16.0	11.6	7960.	9280.	37.9	10.7	8020.	9300.
5	350.	5.6	8.3	8570.	7290.	51.0	13.6	8630.	7310.
6	396.	24.9	6.6	9110.	6690.	16.7	13.8	9150.	6710.
7	0.	13.1	35.7	9460.	8280.	85.3	52.8	9560.	8370.

TABLE D.12. NITROGEN REMOVAL BY BERMUDA

Treatment	Annual Hydraulic Loading (cm)		September 1982			June 1983			September 1983			Total Mass Recovered (kg/ha.yr)	
	1982	1983	Conc. (mg/g)	Yield (kg/ha)	Mass (kg/ha)	Conc. (mg/g)	Yield (kg/ha)	Mass (kg/ha)	Conc. (mg/g)	Yield (kg/ha)	Mass (kg/ha)	1982	1983
1	38.	152.	17.36	3968.	68.9	19.64	5112.	100.4	11.95	9368.	111.9	68.9	212.3
2	46.	198.	19.88	4970.	98.8	13.89	4138.	57.5	12.03	8174.	98.3	98.8	155.8
3	76.	259.	20.60	3525.	72.6	14.38	4650.	66.9	13.09	6453.	84.5	72.6	151.4
4	91.	305.	17.14	4493.	77.0	16.93	4525.	76.6	11.76	7261.	85.4	77.0	162.0
5	122.	350.	18.95	5493.	104.1	16.31	3875.	63.2	9.67	6471.	62.6	104.1	125.8
6	152.	396.	18.12	4299.	77.9	15.64	4650.	72.7	10.24	7094.	72.6	77.9	145.3
7	0.	0.	14.56	2297.	33.4	18.49	3350.	61.9	13.09	2926.	38.3	33.4	100.2

APPENDIX E

Mass Balances

TABLE E-1. PHOSPHORUS MASS BALANCE IN GRAIN SORGHUM TEST PLOTS, TRIAL 15000

Annual Hydraulic Loading (cm)	Treatment	Mass P Applied to Plot (kg/ha)	Mass P in Soil Profile		Mass P Utilized by Crop	Unaccounted for Mass kg/ha
			March 1983	Dec. 1983		
0.	5	0	5720.	3930.	4.4	-1788
137	1	101.5	3930.	4140.	17.7	+129.
183	2	135.6	4180.	3880.	30.0	-405.
213	3	157.8	4010.	3880.	30.2	-256.
282	4	209.0	4180.	4180.	34.9	-174.1

TABLE E-2. PHOSPHORUS MASS BALANCE OF COTTON TEST PLOTS, TRIALS 14000 and 15000

Trial	Phosphorus Mass Treatment	Annual Hydraulic Loading (cm)	Phosphorus Mass Applied (kg/ha)	Crop Uptake of Phosphorus (kg/ha)	Phosphrous Mass in Soil Profile (kg/ha)		Unaccounted Phosphorus (kg/ha)
					Winter 1983	Fall 1983	
14000	2	0.	0	2.1	2090	2260	+172.
	4	20.	14.8	8.7	2090	2480	+384.
	6	41.	30.4	1.9	2090	2390	+272.
	8	51.	37.8	12.7	2090	2560	+445.
	10	61.	45.2	10.4	2090	2520	+395.
	12	69.	51.1	8.3	2090	2180	+47.
	14	86.	63.7	11.9	2090	2300	+158.
	16	102.	75.6	12.1	2090	2560	+406.
15000	1	122.	90.4	22.5	4350	3800	-618.
	2	183.	135.6	27.3	4650	5100	-342.
	3	229.	169.7	26.8	3930	2990	-1080.
	4	297.	220.1	25.6	4480	3410	-1260.
	5	0.	0.0	5.1	4310	3710	-595.

TABLE E.3. PHOSPHORUS MASS BALANCE IN ALFALFA TEST PLOTS, TRIAL 16000

Treat-ment	Annual Hydraulic Loading (cm)	Phosphorus Mass Applied (kg/ha)	Phosphorus Mass Removed by Crop (kg/ha)	Phosphorus Mass in Soil Profile (kg/ha)		Unaccounted Mass (kg/ha)
				Feb. 1983	Dec. 1983	
1	137.	101.5	31.34	3670.	6910.	+3170.
2	198.	146.7	38.61	3540.	3710.	+61.
3	259.	191.9	38.53	4220.	3200.	-1173.
4	305.	226.0	44.01	7640.	6830.	-992.
5	365 .	270.5	51.00	3800.	2600.	-1420.
6	434.	321.6	54.44	4050.	2860.	-1457.
7	0.	0.0	9.58	4220.	4100.	-110.
*10	365.	0.0	18.61	3800.	2600.	-1181.
*11	305.	0.0	16.70	3800.	3200.	-583.
*12	259.	0.0	14.03	4010.	3120.	-876.

*Irrigated with Groundwater

TABLE E.4. PHOSPHORUS MASS BALANCE IN BERMUDA TEST PLOTS, TRIAL 16000

Treat-ment	Annual Hydraulic Loading (cm)	Phosphorus Mass Applied through irrigation (kg-P/ha.yr)	Phosphorus Mass Utilized by Crop (kg-P/ha.yr)	Phosphorus Mass in the Soil Profile (kg-P/ha.yr)		Unaccounted Mass (kg-P/ha.yr)
				Feb 1983	Dec 1983	
1	152.	113.	18.7	4270.	3800.	-564.
2	198.	147.	17.7	3930.	3670.	-389.
3	259.	192.	17.3	4520.	3840.	-855.
4	305.	226.	20.1	4440.	4140.	-506.
5	350.	259.	17.4	4310.	4440.	-112.
6	396.	294.	18.9	4400.	4520.	-155.
7	0.	0.	5.9	4440.	3580.	-854.

TABLE E.5. PHOSPHORUS MASS BALANCE IN GRAIN SORGHUM TEST PLOTS, TRIAL 17000

Treatment	Annual Hydraulic Loading (cm)	Phosphorus Mass Applied (kg-P/ha.yr)	Phosphorus Mass Utilized by Crop (kg/ha.yr)	Phosphorus Mass in Profile (kg/ha) July 1982	Phosphorus Mass in Profile (kg/ha) Nov. 1982	Unaccounted Phosphorus Mass (kg/ha)
1	30	33.0	6.2	2010	2090.	+53.2
2	30	33.0	5.3		2390.	+352.
3	30	33.0	12.4		2180.	+149.
4	30	33.0	5.4		2220.	+182.
5	61	67.0	8.8		2010.	-58.
6	61	67.0	5.3		2940.	+868.
7	61	67.0	6.9		2090.	+20.
8	61	67.0	11.5		2180.	+114.
9	122	134.1	9.0		2300.	+165.
10	122	134.1	8.1		2650.	+514.
11	122	134.1	11.0		2730.	+597.
12	122	134.1	12.9		2480.	+349.

TABLE E.6. PHOSPHORUS MASS BALANCE IN SOYBEANS TEST PLOTS, TRIAL 17000

Treat-ment	Annual Hydraulic Loading (cm)	Phosphorus Mass Applied (kg-P/ha.yr)	Phosphorus Mass Utilized by Crop (kg/ha.yr)	Phosphorus Mass in Profile (kg/ha)		Unaccounted Phosphorus Mass (kg/ha)
				July 1982	Nov. 1982	
1	30	33.0	8.8	2350.	2050.	-324.
2	30	33.0	7.6	2350.	1960.	-415.
3	30	33.0	8.2	2350.	2300.	-75.
4	30	33.0	7.8	2350.	2130.	-245.
5	61	67.0	6.8	2350.	2300.	-110.
6	61	67.0	6.7	2350.	2180.	-230.
7	61	67.0	7.0	2350.	2390.	-20.
8	61	67.0	5.0	2350.	2350.	-62.
9	122	134.1	6.9	2350.	2090.	-387.
10	122	134.1	6.9	2350.	2090.	-387.
11	122	134.1	7.2	2350.	2090.	-387.
12	122	134.1	6.8	2350.	1960.	-517.

TABLE E-7. TOTAL DISSOLVED SOLIDS (TDS) MASS BALANCE IN GRAIN SORGHUM (MILO) PLOT, TRIAL 15000

Annual Hydraulic Loading (cm)	Mass TDS Applied (kg/ha)	TDS in Profile (kg/ha)		Unaccounted Mass (kg/ha)
		March 1983	Dec. 1983	
0.	0.0	13,500	11,300	-2,202.
137	16,900.	10,700	13,400	-14,200.
183.	22,500.	11,900	12,000	-22,400.
213.	26,200.	11,500	15,000	-22,700.
282.	34,700.	11,400	14,300	-31,807.

TABLE E-8. TOTAL DISSOLVED SOLIDS (TDS) MASS BALANCE ON COTTON TEST PLOTS TRIALS 14000 AND 15000

Trial	Treat-ment	TDS Applied (kg/ha)	TDS in Soil Profile (kg/ha) Winter 1983	Fall 1983	Unaccounted Mass (kg/ha)
14000	2	0	3540.	5160.	+1620.
	4	2460.	3540.	6360.	+360.
	6	5040.	3540.	6400.	-2190.
	8	6280.	3540.	6400.	-3420.
	10	7510.	3540.	7250.	-3800.
	12	8490.	3540.	7980.	-4050.
	14	10,600.	3540.	7940.	-6200.
	16	12,600.	3540.	7510.	-8630.
	18	15,000.	3540.	7680.	-10,900.
15000	1	15,000.	9130.	9730.	-14,400.
	2	22,500.	9980.	12,000.	-20,500.
	3	28,200.	9960.	12,600.	-25,600.
	4	36,600.	11,500.	17,200.	-30,900.
	5	0	9560.	9520.	-43.

TABLE E-9. TOTAL DISSOLVED SOLIDS MASS BALANCE ON TRIAL 16000 ALFALFA PLOTS

Treat-ment	Annual Hydraulic Loading (cm)	Mass Applied (kg/ha)	Total Dissolved Solids in Soil Profile (kg/ha)		Unaccounted Mass (kg/ha)
			February 1983	December 1983	
1	137.	16,900.	10,200.	15,009.	-12,000.
2	198.	24,400.	10,700.	19,600.	-15,500.
3	259.	31,900.	10,800.	18,400.	-24,300.
4	305.	37,500.	16,100.	21,800.	-31,800.
5	365.	44,900.	10,500.	19,800.	-35,600.
6	434.	53,400.	11,200.	13,700.	-50,900.
7	0.	0.	9,000.	9,130.	+130.
*10	365.	26,100.	8,790.	7,000.	-27,900.
*11	305.	21,800.	8,320.	7,340.	-22,800.
*12	259.	18,300.	9,220.	8,790.	-18,700.

*Irrigated with Groundwater

TABLE E.10. TOTAL DISSOLVED SOLIDS (TDS) MASS BALANCE IN BERMUDA GRASS

Treat-ment	Annual Hydraulic Loading (cm)	TDS Mass Applied (kg/ha)	TDS in Soil Profile (kg/ha)		Unaccounted Mass (kg/ha)
			February 1983	December 1983	
1	152.	18,700.	10,200.	11,900	-17,000.
2	198.	24,400.	11,900.	13,200.	-23,100.
3	259.	31,900.	11,400.	13,100.	-30,200.
4	305.	37,500.	9,980.	17,200.	-30,300.
5	350.	43,100.	10,400.	15,400.	-38,100.
6	396.	48,700.	10,500.	16,400.	-42,800.
7	0.	0.	10,400.	10,700.	+300.

TABLE E-11. TOTAL DISSOLVED SOLIDS (TDS) MASS BALANCE ON GRAIN SORGHUM TEST PLOTS, TRIAL 17000

Treatment	Annual Hydraulic Loading (cm)	TDS Mass Applied (kg/ha)	TDS Mass in Soil Profile (Kg/ha)		Unaccounted for Mass (kg/ha)
			July 1982	Nov. 1982	
1	30	3590.	3580.	4570.	-2600.
2	30	3590.	3580.	4780.	-2390.
3	30	3590.	3580.	4310.	-2860.
4	30	3590.	3580.	4440.	-2730.
5	61	7310.	3580.	4350.	-6540.
6	61	7310.	3580.	4050.	-6840.
7	61	7310.	3580.	4570.	-6320.
8	61	7310.	3580.	4050.	-6840.
9	122	14,600.	3580.	4910.	-13,300.
10	122	14,600.	3580.	4570.	-13,600.
11	122	14,600.	3580.	4350.	-13,800.
12	122	14,600.	3580.	4780.	-13,400.

TABLE E-12. TOTAL DISSOLVED SOLIDS (TDS) MASS BALANCE ON SOYBEAN TEST PLOTS, TRIAL 17000

Treatment	Annual Hydraulic Loading (cm)	TDS Mass Applied (kg/ha)	TDS Mass in Soil Profile (Kg/ha)		Unaccounted for Mass (kg/ha)
			July 1982	Nov. 1982	
1	30	3590.	4480.	3800.	-4270.
2	30	3590.	4480.	3460.	-4610.
3	30	3590.	4480.	5680.	-2390.
4	30	3590.	4480.	5160.	-2010.
5	61	3590.	4480.	4690.	-3380.
6	61	7310.	4480.	4910.	-6880.
7	61	7310.	4480.	5250.	-6540.
8	61	7310.	4480.	5500.	-6290.
9	122	14,600.	4480.	4140.	-14,900.
10	122	14,600.	4480.	5590.	-13,500.
11	122	14,600.	4480.	6960.	-12,100.
12	122	14,600.	4480.	5250.	-13,800.

TABLE E-13. SODIUM MASS BALANCE ON GRAIN SORGHUM (MILO) TEST PLOTS, TRIAL 15000

Annual Hydraulic Loading Rate (cm)	Sodium Mass Applied (kg/ha)	Sodium Mass in Soil Profile (kg/ha)		Unaccounted Sodium Mass (kg/ha)
		March 1983	Dec. 1983	
0	0	6790.	5630.	-1160.
137	4210.	5490.	4270.	-5430.
183	5620.	6345.	4040.	-7920.
213	6540.	6060.	4680.	-7920.
282	6860.	6380.	9210.	-4039.

TABLE E.14. SODIUM MASS BALANCE ON COTTON TEST PLOTS TRIALS 14000 AND 15000

Trial	Treat-ment	Sodium Mass Applied (kg/ha)	Sodium Mass in Soil Profile (kg/ha) Winter 1983	Sodium Mass in Soil Profile (kg/ha) Fall 1983	Unaccounted Mass (kg/ha)
14000	2	0	2050.	1840.	-210.
	4	614.	2050.	2140.	-520.
	6	1260.	2050.	2030.	-1280.
	8	1570.	2050.	2020.	-1590.
	10	1870.	2050.	2860.	-1060.
	12	2120.	2050.	2960.	-1200.
	14	2640.	2050.	2090.	-1590.
	16	3130.	2050.	2990.	-2190.
	18	3740.	2050.	3690.	-2100.
15000	1	3740.	5170.	6420.	-2490.
	2	5620.	5360.	7500.	-3480.
	3	7030.	5240.	5540.	-6720.
	4	9120.	5570.	8880.	-5810.
	5	0	5100.	4240.	-860.

TABLE E-15. SODIUM MASS BALANCE ON TRIAL 16000 ALFALFA PLOTS

Treat-ment	Annual Hydraulic Loading (cm)	Mass Applied (kg/ha.yr)	Mass Uptake by Crop (kg/ha.yr)	Mass in Soil Profile (kg/ha.yr)		Unaccounted Mass (kg/ha.yr)
				Feb. 1983	Dec. 1983	
1	137.	4210.	15.4	6590.	9230.	-1555.
2	198.	6080.	17.1	5640.	9280.	-2420.
3	159.	7950.	19.0	5680.	9550.	-4060
4	305.	9360.	21.2	8110.	10,800	-6650.
5	365.	11,200.	26.7	5530.	8880.	-7823.
6	434.	13,300.	29.0	8010.	9030.	-12,300.
7	0.	0.	1.7	7080.	6730.	-348.
10	365.	3840.	4.7	4460.	6840.	-1455.
11	305.	3210.	4.2	4380.	5500.	-2090.
12	259.	2730.	3.2	5030.	6110.	-1650.

TABLE E-16. SODIUM MASS BALANCE IN BERMUDA TEST PLOTS, TRIAL 16000

Treatment	Annual Hydraulic Loading (cm)	Sodium Mass Applied (kg/ha/yr)	Sodium Mass Uptake by Crop (kg/ha/yr)	Sodium Mass in Soil Profile (kg/ha/yr) February 1983	Sodium Mass in Soil Profile (kg/ha/yr) December 1983	Unaccounted Mass (kg/ha/yr)
1	152.	4670.	4.5	5780.	6050.	-4400.
2	198.	6080.	4.9	5700.	6590.	-5190.
3	259.	7950.	5.7	6100.	6960.	-7080.
4	305.	9360.	11.8	5870.	6970.	-8250.
5	350.	10,700.	6.8	6960.	10,500.	-7150.
6	396.	12,200.	5.5	5860.	6890.	-11,200.
7	0.	0	0.6	5070.	4990.	-79.

TABLE E.17. SODIUM MASS BALANCE ON GRAIN SORGHUM TEST PLOTS, TRIAL 17000

Treatment	Annual Hydraulic Loading (cm)	Sodium Mass Applied (kg/ha.yr)	Sodium Mass in Soil Profile (Kg/ha) July 1982	Sodium Mass in Soil Profile (Kg/ha) Nov. 1982	Unaccounted for Mass (kg/ha)
1	30	948.	3020.	2980.	-981.
2	30	948.	3020.	2100.	-1870.
3	30	948.	3020.	2280.	-1690.
4	30	948.	3020.	2550.	-1420.
5	61	1930.	3020.	2940.	-2010.
6	61	1930.	3020.	2550.	-2400.
7	61	1930.	3020.	2160.	-2790.
8	61	1930.	3020.	2880.	-2070.
9	122	3860.	3020.	2680.	-4200.
10	122	3860.	3020.	2730.	-4150.
11	122	3860.	3020.	2800.	-4080.
12	122	3860.	3020.	2500.	-4386.

TABLE E-19. POTASSIUM MASS BALANCE FOR GRAIN SORGHUM TEST PLOTS, TRIAL 16000

Annual Hydraulic Loading (cm)	Potassium Mass Applied (kg/ha)	Potassium Mass in Soil Profile (kg/ha)		Crop Uptake (kg/ha)	Unaccounted Mass (kg/ha)
		March 1983	Dec. 1983		
0.	0.	81,400.	82,000.	53.7	+654.
137.	412.	72,000	70,200.	102.3	-2110.
183.	551.	80,000.	72,200.	122.1	-8230.
213.	641.	81,400.	71,100.	129.1	-10,800.
282.	849.	82,100.	72,700.	128.3	-10,100.

TABLE E-20. POTASSIUM MASS BALANCE ON COTTON TEST PLOTS TRIALS 14000 AND 15000

Trial	Treat-ment	Potassisum Mass Applied (kg/ha)	Potassium Mass Removed by Cotton (kg/ha)	Potassium Mass in Soil Profile (kg/ha)		Unaccounted Potassium Mass (kg/ha)
				Winter 1983	Fall 1983	
14000	2	0.	21.6	54,500.	40,920.	-13,608.
	4	39.	51.4	54,500.	48,000.	-6,490.
	6	80.	38.8	54,500.	41,300.	-13,200.
	8	100.	56.4	54,500.	42,800.	-11,700.
	10	119.	36.5	54,500.	44,200.	-10,400.
	12	135.	60.2	54,500.	57,100.	+2,530.
	14	168.	51.8	54,500.	44,600.	-10,000.
	16	199.	43.0	54,500.	39,300.	-15,400.
	18	238.	51.9	54,500.	36,300.	-18,400.
15000	1	238.	41.6	69,600.	54,400.	-15,400.
	2	357.	36.1	67,400.	61,700.	-6,020.
	3	447.	38.4	67,500.	52,800.	-15,100.
	4	579.	58.6	69,900.	64,800.	-5,620.
	5	0.	8.3	68,200.	69,600.	+1,410.

TABLE E-22. POTASSIUM MASS BALANCE ON BERMUDA TEST PLOTS, TRIAL 16000

Treat-ment	Annual Hydraulic Loading (cm)	Potassium Mass Applied (kg/ha/yr)	Potassium Mass Uptake by Crop (kg/ha/yr)	Potassium Mass in Soil Profile (kg/ha/yr)		Unaccounted Mass (kg/ha/yr)
				February 1983	December 1983	
1	152.	296.	220.	72,900	84,400	+11,401.
2	198.	386.	198.	74,700	71,000	-3,890.
3	259.	517.	174.	80,300	62,400	-18,200.
4	305.	595.	188.	80,900	58,800	-22,500.
5	350.	683.	146.	73,400	71,600	-2,340.
6	396.	790.	198.	74,500	76,900	+1,810.
7	0.	0.	86.	*28,300	26,500	-1,714.

* Mass balance computed on a 61 cm soil core analyzed in December 1983

TABLE E-23. POTASSIUM MASS BALANCE ON GRAIN SORGHUM TEST PLOTS, TRIAL 17000

Treatment	Annual Hydraulic Loading (cm)	Potassium Mass Applied (kg/ha)	Potassium Uptake by Crop (kg/ha)	Potassium Mass in Profile (Kg/ha) July 1982	Nov. 1982	Unaccounted for Mass (kg/ha)
1	30	58.	80.	63,500.	27,822.	
2	30	58.	121.	63,500.	42,032.	
3	30	58.	59.	63,500.	49,030.	
4	30	58.	161.	63,500.	45,232.	
5	61	119.	81.	63,500.	23,086.	
6	61	119.	97.	63,500.	44,080.	
7	61	119.	123.	63,500.	44,080.	
8	61	119.	146.	63,500.	45,190.	
9	122	238.	158.	63,500.	18,818.	
10	122	238.	46.	63,500.	47,238.	
11	122	238.	118.	63,500.	54,748.	
12	122	238.	150.	63,500.	45,872.	

TABLE E-24. POTASSIUM MASS BALANCE ON SOYBEANS, TRIAL 17000

Treatment	Annual Hydraulic Loading (cm)	Potassium Mass Applied (kg/ha)	Potassium Uptake by Crop (kg/ha)	Potassium Mass in Profile (Kg/ha) July 1982	Nov. 1982	Unaccounted for Mass (kg/ha)
1	30	58.	39.	67,700.	36,900.	
2	30	58.	33.	67,700.	48,600.	
3	30	58.	34.	67,700.	40,200.	
4	30	58.	38.	67,700.	40,300.	
5	61	119.	36.	67,700.	35,400.	
6	61	119.	36.	67,700.	39,200.	
7	61	119.	32.	67,700.	22,700.	
8	61	199.	28.	67,700.	28,800.	
9	122	238.	31.	67,700.	41,900.	
10	122	238.	29.	67,700.	43,700	
11	122	238.	45.	67,700.	49,500.	
12	122	238.	44.	67,700.	37,800.	

TABLE E-25. CHLORIDE MASS BALANCE FOR GRAIN SORGHUM TEST PLOTS, TRIAL 15000

Annual Hydraulic Loading (cm)	Chloride Mass Applied (kg/ha)	Chloride Mass in Soil Profile (kg/ha)		Crop Uptake (kg/ha)	Unaccounted Mass (kg/ha)
		March 1983	Dec. 1983		
0.	0.	1700.	644.	25	-1030.
137.	4,870.	1070.	2010.	39	-3890.
183.	6,510.	1310.	1690.	42	-6090.
213.	7,580.	1260.	1890.	53	-6900.
282.	10,000.	1820.	1670.	40	-10,100.

TABLE E.26. CHLORIDE MASS BALANCE ON COTTON TEST PLOTS TRIALS 14000 AND 15000

Trial	Treatment	Chloride Mass Applied (kg/ha)	Chloride Mass in Soil Profile (kg/ha) Winter 1983	Chloride Mass in Soil Profile (kg/ha) Fall 1983	Unaccounted Chloride Mass (kg/ha)
14000	2	0.	59.	448.	+389.
	4	712.	59.	862.	+91.
	6	1460.	59.	1170.	-349.
	8	1820.	59.	1070.	-809.
	10	2170.	59.	836.	-1390.
	12	2460.	59.	1610.	-909
	14	3060.	59.	1250.	-1870.
	16	3630.	59.	1650.	-2040.
	18	4340.	59.	1320.	-3080.
15000	1	4340.	512.	1090.	-3760.
	2	6510.	981.	2260.	-5230.
	3	8150.	1280.	2460.	-6970.
	4	10,600.	1710.	2970.	-9340.
	5	0.	341.	499.	+158.

TABLE E-27. CHLORIDE MASS BALANCE FOR TRIAL 16000 ALFALFA PLOTS

Treat-ment	Annual Hydraulic Loading (cm)	Chloride Mass Applied (kg/ha.yr)	Chloride Mass Consumed by Crop (kg/ha.yr)	Chloride Mass in Soil Profile		Unaccounted Chloride Mass (kg/ha.yr)
				Feb. 1983	Dec 1983	
1	137.	4870.	104.	706.	2860.	-2610.
2	198.	7040.	186.	896.	4070.	-3680.
3	259.	9220.	198.	1070.	2780.	-7310.
4	305.	10,900.	225.	1840.	4470.	-8040.
5	365.	13,000.	243.	1200.	3150.	-10,800.
6	434.	15,400.	240.	1450.	2420.	-14,200.
7	0.	0.	24.	299.	644.	+369.
10	365.	2770.	60.	384.	640.	-2450.
11	305.	2320.	60.	384.	853.	-1790.

TABLE E.28. CHLORIDE MASS BALANCE IN BERMUDA TEST PLOTS, TRIAL 16000

Treatment	Annual Hydraulic Loading (cm)	Chloride Mass Applied (kg/ha/yr)	Chloride Mass Uptake by Crop (kg/ha/yr)	Chloride Mass in Soil Profile (kg/ha/yr)		Unaccounted Mass (kg/ha/yr)
				February 1983	December 1983	
1	152.	5410.	118.	589.	3490.	-2390.
2	198.	7050.	84.	4100.	4310.	-6760.
3	259.	9220.	80.	1200.	3230.	-7110.
4	305.	10,900.	76.	1110.	4810.	-7120.
5	350.	12,500.	62.	1450.	2320.	-11,600.
6	396.	14,100.	74.	1280.	2410.	-12,900.
7	0.	0	51.	555.	1180.	+676.

TABLE E-29. SULFATE MASS UPTAKE IN BERMUDA

Treatment	Annual Hydraulic Loading (cm)	Sulfate Mass Applied (kg/ha/yr)	Sulfate Mass in Soil Profile (kg/ha/yr)		Unaccounted Mass (kg/ha/yr)
			February 1983	December 1983	
1	152.	3070.	2650.	2480.	-3240.
2	198.	4000.	3070.	2220.	-4850.
3	259.	5230.	2730.	2720.	-5240.
4	305.	6160.	1840.	3060.	-4940.
5	350.	7070.	1920.	2910.	-6080.
6	396.	8000.	2260.	3130.	-7130.
7	0.	0	2390.	1890.	-500.

TABLE E.30. MASS OF PHOSPHORUS IN THE SOIL PROFILE BENEATH COTTON TEST PLOTS IN TRIALS 14000 AND 15000

Trial	Treat-ment	Annual Hydraulic Loading (cm)	Total Phosphorus (kg/ha)		Organic Phosphorus (kg/ha)		Inorganic Phosphorus (kg/ha)	
			Winter 1983	Fall 1983	Winter 1983	Fall 1983	Winter 1983	Fall 1983
14000*	2	0.	2090.	2260.	683.	853.	1410.	1410.
	4	20.		2480.		597.		1880.
	6	41.		2390.		853.		1540.
	8	51.		2560.		853.		1710.
	10	61.		2520.		768.		1750.
	12	69.		2180.		640.		1540.
	14	86.		2300.		683.		1620.
	16	102.		2560.		555.		2000.
15000**	1	122.	4350.	3800.	1490.	1200.	2860.	2600.
	2	183.	4650.	4100.	811.	811.	3840.	3280.
	3	229.	3930.	2990.	811.	853.	3120.	2130.
	4	297.	4480.	3410.	1540.	853.	2940.	2560.
	5	0.	4310.	3710.	1490.	1370.	2820.	2350.

* 91 cm Depth to Soil Core
** 183 cm Depth to Soil Core

TABLE E.31. PHOSPHORUS REMOVAL BY ALFALFA - TRIAL 16000

Treat-ment	Annual Hydraulic Loading (cm) 1982	1983	September 1982 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	May 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	June 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	August 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)
1	23.	137.	1.77	1700	3.01	1.68	3520	5.91	2.35	3390.	7.99	2.30	2830	6.51
2	46.	198.	1.99	1260	2.51	1.79	3820	6.85	2.43	4730.	11.49	2.58	3380	8.72
3	76.	259.	1.73	1600	2.77	1.68	3610	6.06	2.41	4620.	11.15	2.62	3550	9.30
4	107.	305.	2.20	2350	5.17	2.08	3730	7.76	2.58	4690.	12.09	2.74	3260	8.93
5	137.	365.	1.73	1700	2.94	2.63	3680	9.68	2.42	5800.	14.04	2.55	4150	10.58
6	137.	434.	2.68	1650	4.42	2.92	4340	12.67	2.64	5460.	13.11	2.71	3930	10.65
7	0.	0.	1.64	650	1.07	1.11	2270	2.52	1.32	2210	2.92	1.45	890	1.29
*10	137.	365.	2.08	1550	3.22	1.23	2630	3.23	2.22	2700	5.99	1.38	2700	3.73
*11	107.	305.	1.95	1750	3.41	1.06	3500	3.71	1.66	2700	4.48	1.46	2240	3.27
*12	76.	259.	1.85	1250	2.31	1.13	2600	2.95	1.37	2100	2.88	1.65	1610	2.66

Treat-ment	Annual Hydraulic Loading (cm) 1981	1983	September 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	November 1983 Plant Tissue Conc. (mg/g)	Crop Yield (kg/ha)	Mass Removed (kg/ha)	TOTAL 1982	1983
1	23.	137.	2.39	2550	6.09	2.08	2380.	4.94	3.01	31.34
2	46.	198.	2.12	3130	6.64	2.17	2260.	4.91	2.51	38.61
3	76.	259.	2.14	3620	7.75	2.06	2080.	4.27	2.77	38.53
4	107.	305.	2.57	3790	9.74	1.91	2880.	5.49	5.17	44.01
5	137.	365.	2.46	4530	11.14	1.90	2920.	5.56	2.94	51.00
6	137.	434.	2.48	4380	12.44	1.82	3060.	5.57	4.42	54.44
7	0.	0.	1.43	----	-0-	1.84	1550.	2.85	1.07	9.58
*10	137.	365.	1.57	1980	3.11	1.20	2120.	2.55	3.22	18.61
*11	107.	305.	1.43	1810	2.59	1.31	2020	2.65	3.41	16.70
*12	76.	259.	1.48	2440	3.61	1.43	1350	1.93	2.31	14.03

*Irrigated with Ground water

TABLE E.32. POTASSIUM UPTAKE BY ALFALFA, TRIAL 16000

Treatment Number	Annual Hydraulic Loading (cm)	Potassium Mass Applied (kg/ha.yr)	Potassium Mass Uptake by Crop (kg/ha.yr)
1	137.	267.	367.
2	198.	386.	360.
3	259.	505.	382.
4	305.	595.	402.
5	365.	712.	492.
6	434.	846.	443.
7	0.	0.	121.
10	365.	307.	251.
11	305.	256.	210.
12	259.	218.	

TABLE E.33. PHOSPHORUS UPTAKE BY BERMUDA

Treat-ment	Annual Hydraulic Loading (cm)	September 1982			June 1983			September 1983			Total (kg/ha.yr)	
		Conc.	Yield	Mass	Conc.	Yield	Mass	Conc.	Yield	Mass	1982	1983
1	152.	1.30	3968	5.2	1.50	5112	7.7	1.18	9368	11.0	5.2	18.7
2	198.	1.54	4970	7.6	1.40	4138	5.8	1.46	8174	11.9	7.6	17.7
3	259.	3.45	3535	12.2	1.70	4650	7.9	1.46	6453	9.4	12.2	17.3
4	305.	1.81	4493	8.1	1.89	4525	8.6	1.58	7261	11.5	8.1	20.1
5	350.	1.56	5493	8.6	1.90	3875	7.4	1.54	6471	10.0	8.6	17.4
6	369.	1.69	4299	7.3	1.72	4650	8.0	1.54	7094	10.9	7.3	18.9
7	0.	0.61	2297	1.4	1.09	3350	3.6	0.77	2926	2.3	1.4	5.9

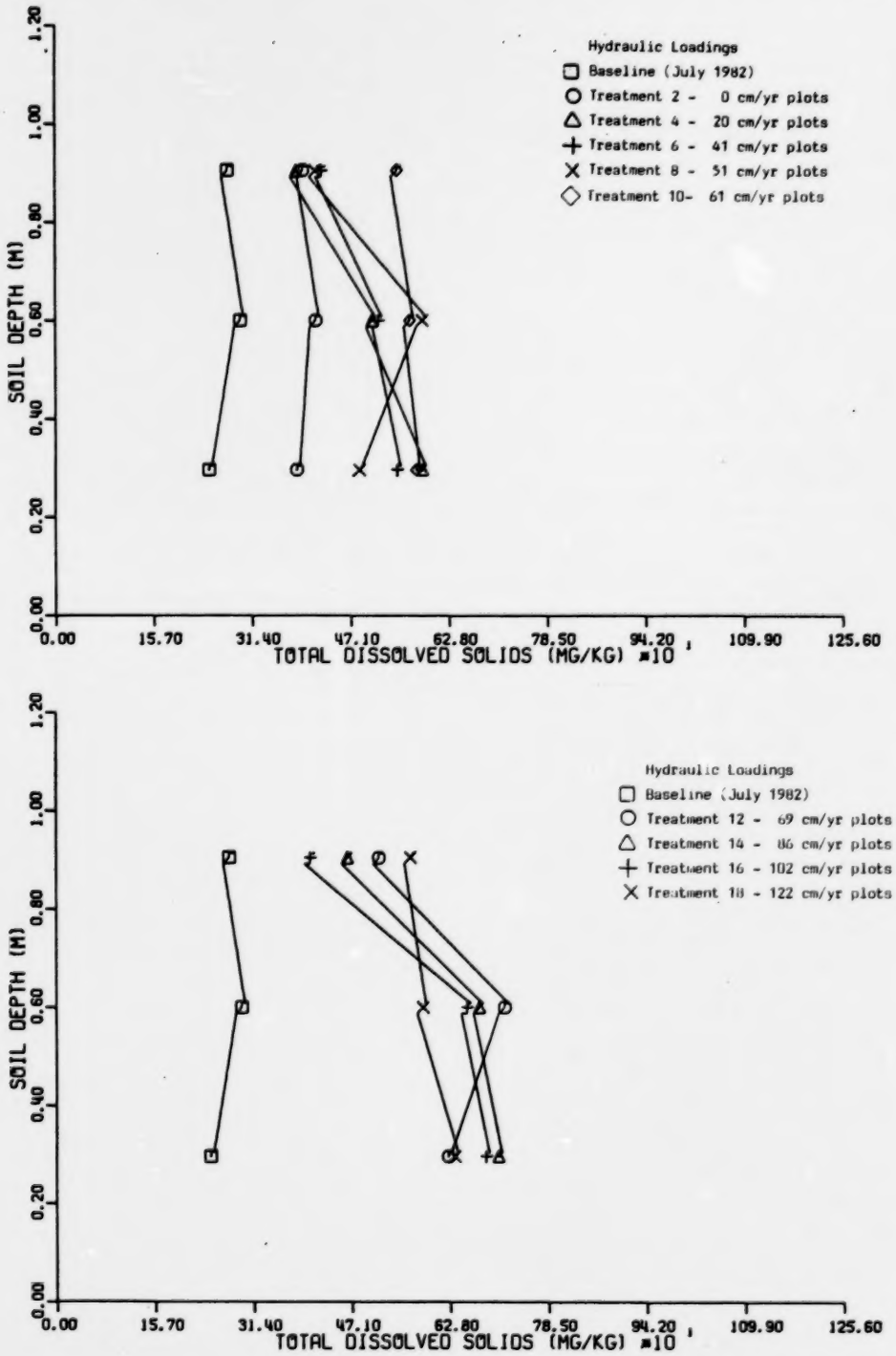
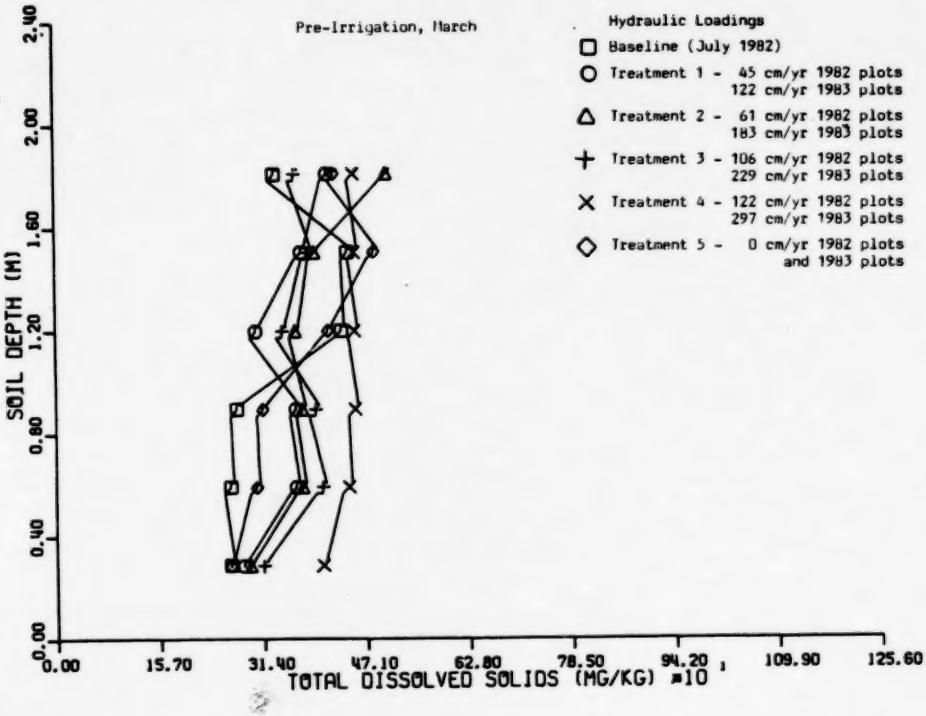


Figure E.1. Total Dissolved Solids in Soil Beneath Trial 14000 Cotton plots, Post-Irrigation, December 1983



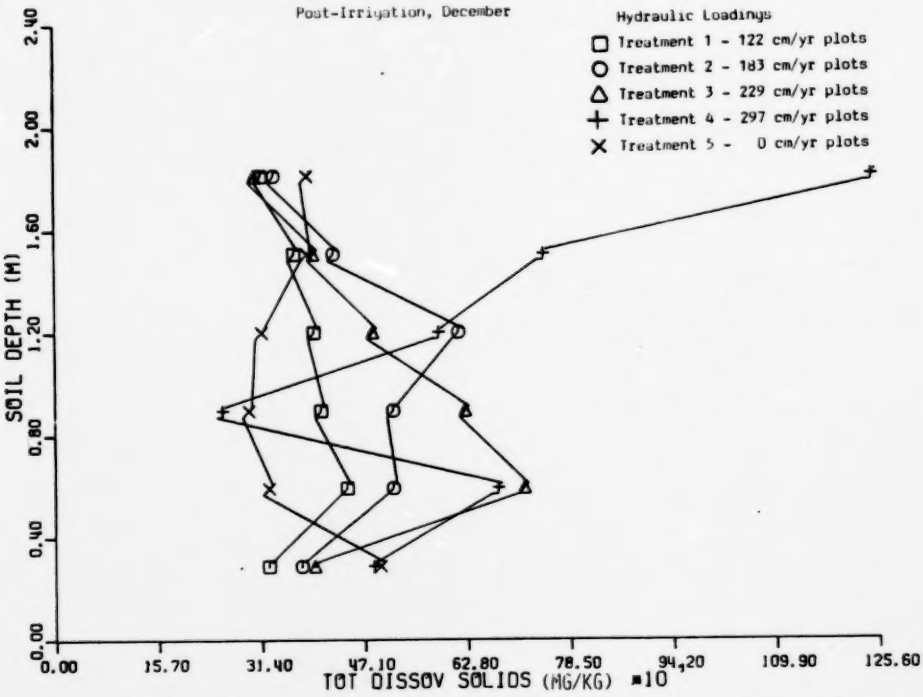


Figure E.2. Total Dissolved Solids in Soil Beneath Trial 15000 Cotton plots, 1983

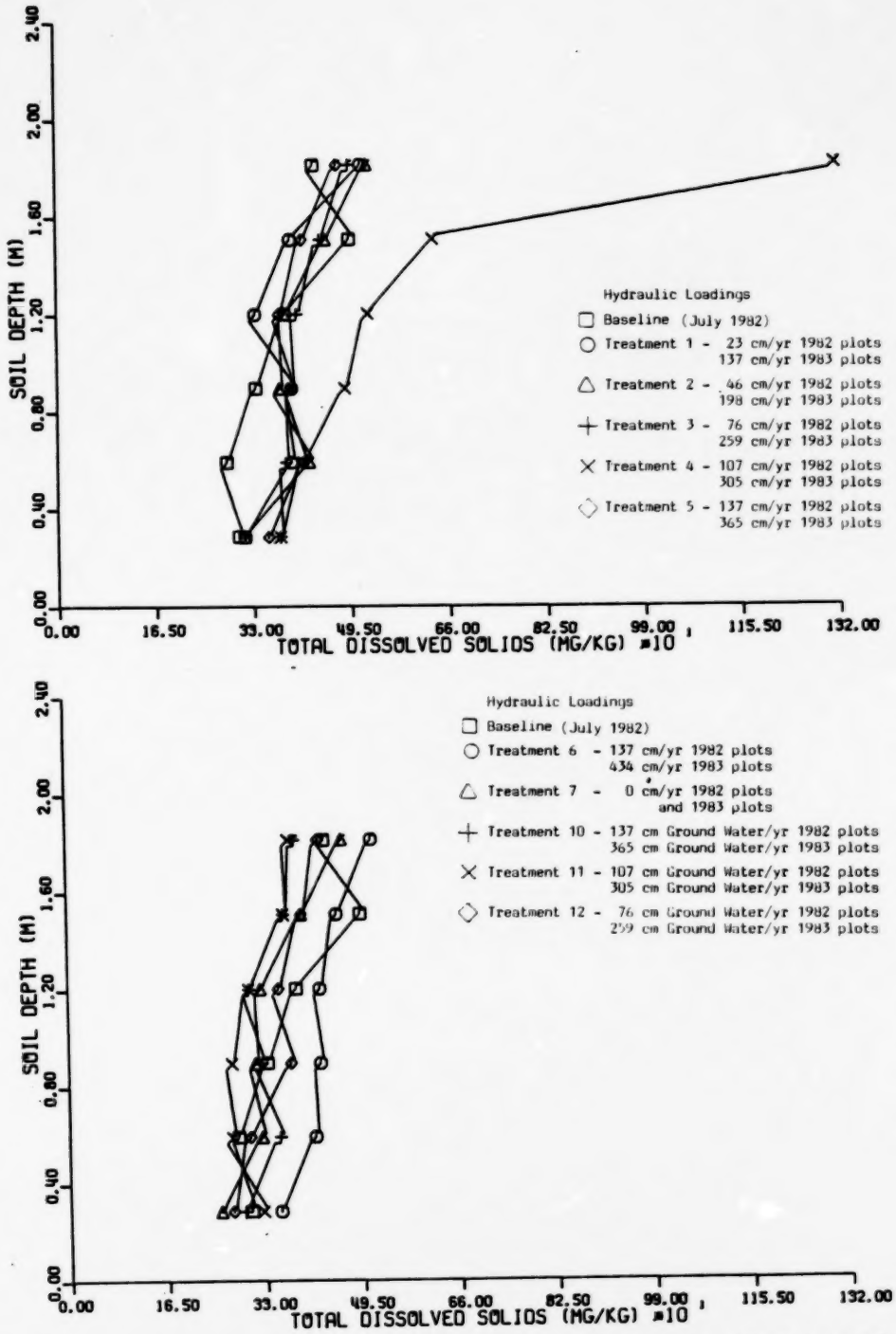
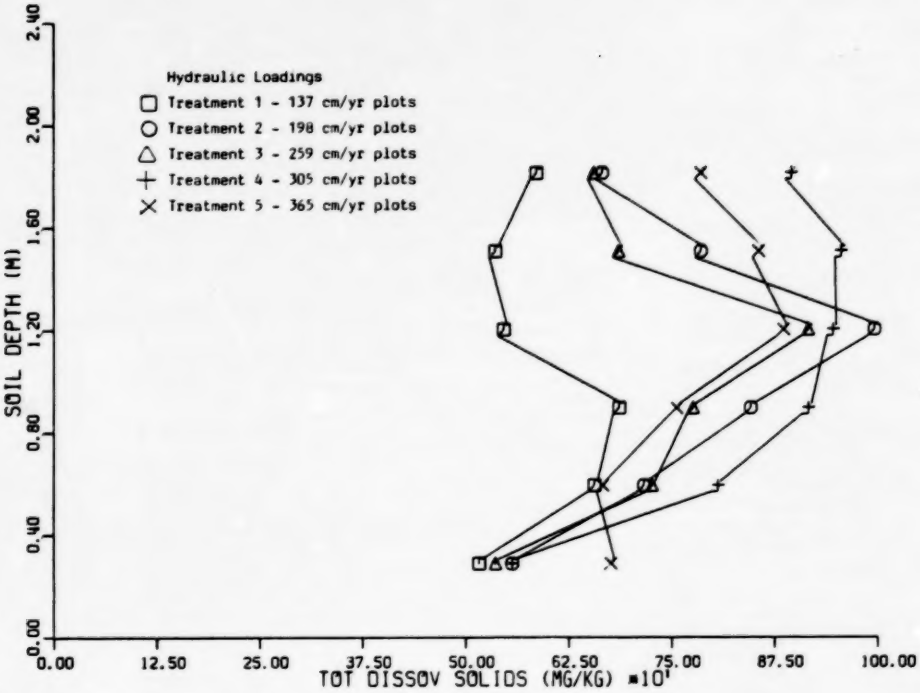


Figure E.3. Total Dissolved Solids in Soil Beneath Trial 16000 Alfalfa Plots, Pre-Irrigation, March 1983



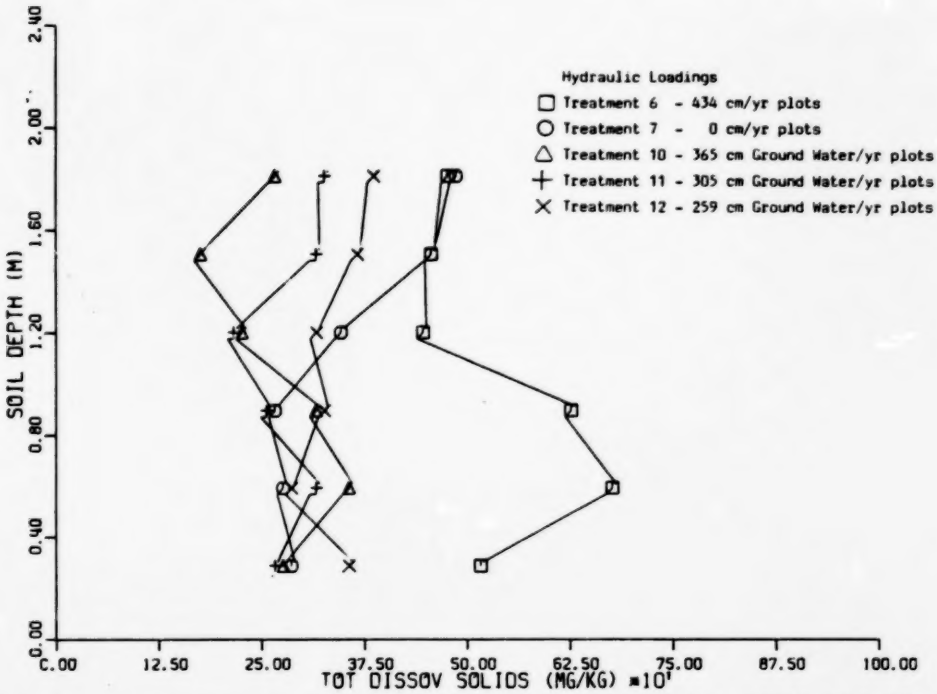


Figure E.4. Total Dissolved Solids in Soil Beneath Trial 16000 Alfalfa Plots, Post-Irrigation, December 1983

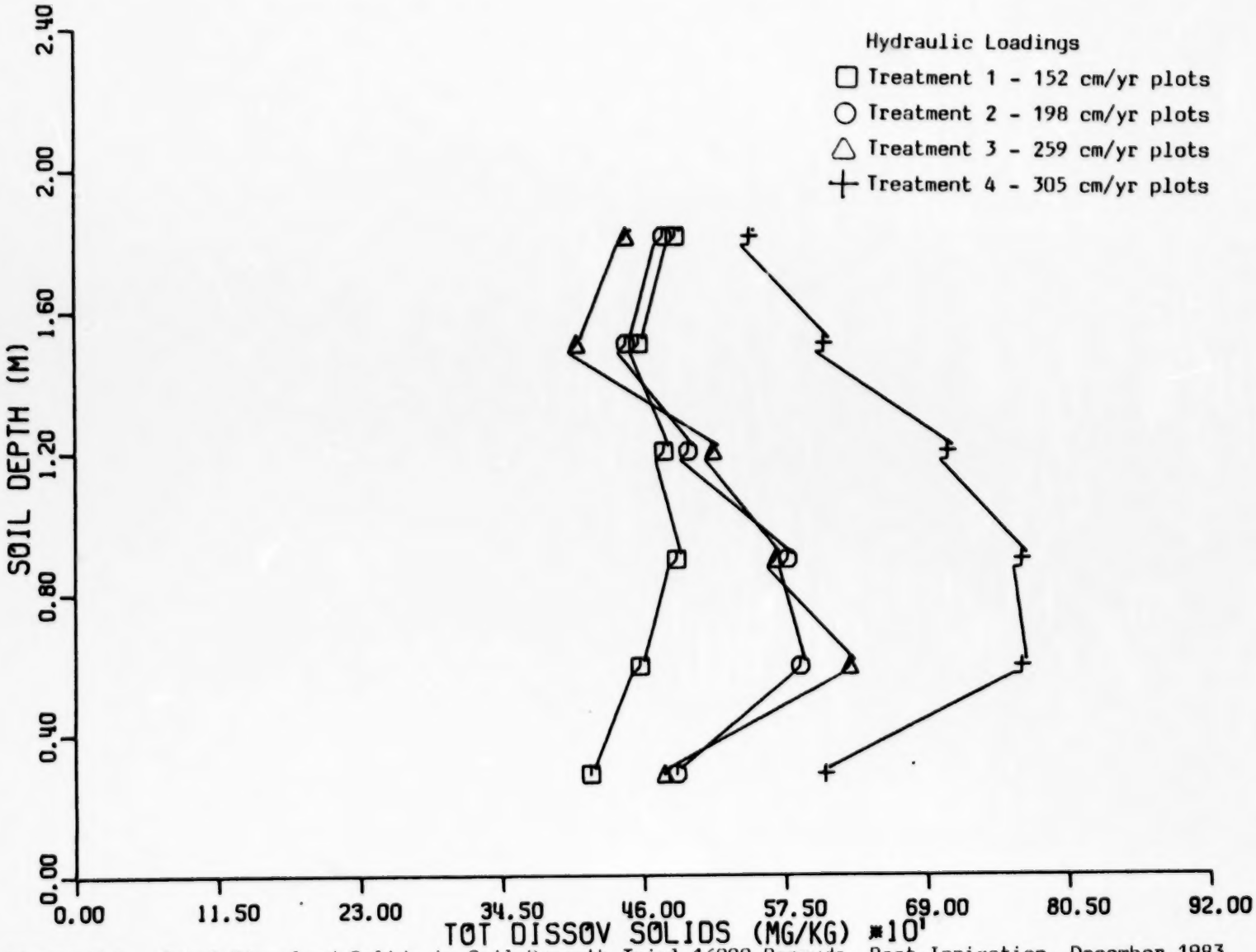


Figure E.5. Total Dissolved Solids in Soil Beneath Trial 16000 Bermuda, Post-Irrigation, December 1983

APPENDIX F

Calculation of the adjusted SAR of Irrigation Water and Soil Exchangeable Sodium Percentage for Test Plots

Table F.1. Calculation of the Adjusted SAR of Irrigation Water (Stromberg and Tisdale 1979)

$$\text{adj. SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \quad [1 + (8.4 - pHc)]$$

$$pHc = (pK'_2 - pK'_c) + p(Ca + Mg) + pAlk$$

pK'_2 is the second dissociation constant for H_2SO_3 and pH_c is the solubility constant for $CaCO_3$ both corrected for ionic strength obtained.

p(Ca +Mg) is the negative logarithm of the molal concentration of calcium plus magnesium.

pAlk is the negative logarithm of the molal concentration of the total bases (CO_3 + HCO_3). Based on pH levels between 7 and 8. It was assumed the bases were primarily HCO_3 and CO_3 was negligible.

pHc is a theoretical, calculated pH of irrigation water in contact with lime in equilibrium with soil CO_2.

($pK'_2 - pK'_c$) is obtained from using the sum of Ca + Mg + Na in meq/l and the following table:

Sum of Concentration (meq/l)	$pK'_2 - pK'_c$	Sum of Concentration (meq/l)	$pK'_2 - pK'_c$
.05	2.0	2.5	2.2
.10	2.0	3.0	2.2
.15	2.0	4.0	2.2
.20	2.0	5.0	2.2
.25	2.0	6.0	2.2
.30	2.0	8.0	2.3
.40	2.0	10.0	2.3
.50	2.1	12.5	2.3
.50	2.1	15.0	2.3
.75	2.1	20.0	2.4
1.00	2.1	30.0	2.4
1.25	2.1	50.0	2.5
1.5	2.1	80.0	2.5
2.0	2.2		

Table F.1, continued

An example of calculating pHc:
A water contains:

$$Ca = 1.82 \text{ meq/l}$$
$$Mg = 0.75 \text{ meq/l}$$
$$Na = 6.70 \text{ meq/l}$$
$$Ca + Mg + Na = 9.27 \text{ meq/l}$$
$$Ca + Mg = 2.57 \text{ meq/l}$$
$$CO_3 + HCO_3 = 0.35 \text{ meq/l}$$
$$CO_3 = 0.05 \text{ meq/l}$$
$$HCO_3 = 0.30 \text{ meq/l}$$

From the table:

$$pK'_2 - pK'_c = 2.3$$
$$p(Ca + Mg)^c = 2.9$$
$$p(Alk) = 3.5$$
$$8.7$$

To calculate SAR_{adj}, substitute in formula:

$$SAR_{adj} = \sqrt{\frac{6.70 \text{ meq/l}}{\frac{2.57 \text{ meq/l}}{2}}} \quad (1 + (8.4 - 8.7) = 4.1$$

Values of pHc greater than 8.4 indicates a tendency to dissolve lime from the soil matrix; values below 8.4 indicate a tendency to precipitate lime from the applied water.

TABLE F.2. EXCHANGEABLE SODIUM PERCENTAGE (ESP) FOR TRIAL 15000, GRAIN SORGHUM PLOTS

	Annual Hydraulic Loading																			
	0.0				137 cm				183 cm				213 cm				282 cm			
	*CEC		ESP		*CEC		ESP		*CEC		ESP		*CEC		ESP		*CEC		ESP	
Depth (cm)	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983	March 1983	Dec. 1983
30	22.	17.	0.3	0.3	17.	14.	2.4	5.3	28.	13.	2.0	7.3	19.	29.	4.4	3.4	19.	18.	4.6	4.54
61	32.	21.	1.5	1.4	35.	18.	0.8	3.1	38.	25.	1.2	3.4	35.	35.	1.4	3.3	36.	35.	1.5	3.9
91	28.	31.	2.6	1.9	37.	38.	1.2	1.1	36.	31.	1.7	1.5	33.	31.	1.5	2.8	36.	30.	1.6	2.7
122	39.	29.	2.3	2.0	33.	30.	1.3	1.8	34.	30.	1.6	1.7	19.	30.	2.6	1.8	35.	33.	1.2	1.4
152	35.	36.	2.0	1.7	34.	35.	1.5	1.5	24.	25.	2.4	2.1	29.	31.	1.9	1.2	36.	28.	1.5	1.9
183	29.	26.	3.2	2.1	34.	29.	1.1	1.6	33.	33.	1.4	1.8	26.	31.	2.2	1.69	34.	36.	1.5	2.22

*CEC and ESP in units of meq/100 g

TABLE F.3 1983 CEC AND ESP FOR SOIL BENEATH TRIALS 14000 AND 15000 BY HYDRAULIC LOADING AND SOIL DEPTH

Trial 14000

Hydraulic Loading/yr	0.0 cm				20 cm				41 cm			
	*CEC		ESP		CEC		ESP		CEC		ESP	
Depth	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall
30	11.	16.	0.9	0.4	11.	19.	0.9	3.5	11.	18.	0.9	5.2
61	29.	30.	0.9	0.6	29.	25.	0.9	2.7	29.	26.	0.9	1.0
91	39.	33.	1.1	1.2	39.	33.	1.1	1.4	39.	28.	1.1	1.1

Hydraulic Loading/yr	51 cm				61 cm				69 cm			
	*CEC		ESP		CEC		ESP		CEC		ESP	
Depth	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall
30	11.	20.	0.9	4.5	11.	18.	0.9	6.3	11.	19.	0.9	6.2
61	29.	24.	0.9	0.8	29.	32.	0.9	1.8	29.	26.	0.9	2.0
91	39.	34.	1.1	1.0	39.	32.	1.1	1.0	39.	32.	1.1	2.4

Hydraulic Loading/yr	86 cm				102 cm				122 cm			
	*CEC		ESP		CEC		ESP		CEC		ESP	
Depth	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall
30	11.	22.	0.9	6.4	11.	19.	0.9	6.4	11.	22.	0.9	6.4
61	29.	34.	0.9	1.6	29.	30.	0.9	1.0	29.	30.	0.9	1.5
91	39.	25.	1.1	2.4	39.	30.	1.1	1.5	39.	29.	1.1	1.22

(continued)

Table F.3, continued

Trial 15000

Hydraulic Loading/yr	0. cm				122. cm				183. cm			
	*CEC		ESP		CEC		ESP		CEC		ESP	
Depth	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall
30	29.	17.	0.1	0.5	18.	16.	1.8	5.6	18.	13.	2.1	9.9
61	35.	27.	0.8	1.0	37.	37.	0.7	2.3	33.	29.	0.7	4.3
91	35.	29.	1.6	1.6	37.	37.	1.1	1.3	39.	32.	1.2	2.3
122	32.	35.	2.0	1.5	30.	35.	1.5	1.5	33.	32.	1.7	1.7
152	29.	24.	1.9	1.6	30.	39.	1.8	1.6	30.	38.	1.9	1.3
183	34.	25.	1.5	1.5	36.	32.	1.4	2.0	32.	31.	1.5	1.4

Hydraulic Loading/yr	229. cm				297. cm			
	*CEC		ESP		CEC		ESP	
Depth	Winter	Fall	Winter	Fall	Winter	Fall	Winter	Fall
30	29.	15.	1.6	6.6	13.	17.	6.0	8.1
61	34.	29.	0.6	3.3	31.	28.	1.8	5.3
91	33.	28.	0.9	1.3	14.	35.	3.0	2.0
122	32.	32.	1.2	0.7	31.	33.	1.2	1.2
152	32.	28.	1.7	1.0	34.	34.	1.7	1.3
183	35.	35.	1.4	1.6	33.	25.	2.2	5.0

*Calculated from available cations

TABLE F.4. CATION EXCHANGE CAPACITY (CEC) AND EXCHANGEABLE SODIUM PERECENTAGE (ESP) FOR TRIAL 16000 ALFALFA PLOTS

	0.0 cm				137. cm				198. cm				259. cm				305. cm			
	CEC*		ESP*		CEC		ESP		CEC		ESP		CEC		ESP		CEC		ESP	
Depth	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec
30	9.	14.	1.1	0.7	17.	16.	2.9	5.1	11.	15.	2.7	6.6	11.	14.	4.6	5.2	16.	14.	4.4	9.1
61	20.	30.	1.0	1.0	24.	20.	1.7	4.0	24.	29.	0.9	4.1	24.	29.	1.2	4.5	26.	42.	2.2	4.1
91	30.	34.	1.3	1.8	35.	37.	2.3	1.9	34.	37.	0.9	1.9	32.	43.	0.6	1.4	35.	41.	2.0	2.4
122	32.	34.	1.2	2.1	36.	40.	2.2	1.9	26.	40.	2.0	1.5	27.	42.	1.9	1.2	35.	35.	2.3	2.9
152	29.	40.	1.4	1.7	38.	37.	2.1	2.4	28.	43.	1.8	1.9	26.	41.	1.9	1.7	41.	29.	2.4	4.2
183	27.	36.	1.5	1.4	37.	48.	2.4	2.1	24.	44.	1.2	1.6	30.	33.	1.3	2.7	35.	43.	3.1	2.8

	365. cm				434. cm				+259. cm				+305. cm				+365. cm			
	CEC*		ESP*		CEC		ESP		CEC		ESP		CEC		ESP		CEC		ESP	
Depth	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec	Feb	Dec
30	9.	16.	4.4	7.4	12.	14.	4.2	9.6	17.	15.	1.7	2.6	19.	16.	1.6	2.4	22.	19.	0.9	2.2
61	29.	38.	1.7	4.8	16.	18.	3.1	9.4	21.	32.	1.0	1.6	23.	32.	1.3	2.2	29.		0.7	
91	25.	35.	0.8	3.1	26.	34.	1.5	2.3	30.	24.	1.3	1.7	32.	32.	0.9	1.2	29.	36.	0.7	1.4
122	26.	37.	1.1	1.4	31.	27.	1.0	1.9	22.	32.	2.3	1.6	30.	33.	1.7	0.9	10.	37.	4.1	0.8
152	29.	38.	1.7	1.8	29.	35.	1.4	2.0	25.	35.	2.4	2.0	21.	33.	2.8	1.5	8.	58.	3.9	0.5
183	31.	38.	1.3	2.7	42.	32.	0.9	2.8	27.	37.	2.2	2.2	26.	33.	1.9	2.4	24.	40.	2.5	1.5

+Plots Irrigated with Ground Water
*CEC and ESP in Units of meq/100g

TABLE F.5. CATION EXCHANGE CAPACITY (CEC) AND EXCHANGE SODIUM PERCENTAGE (ESP) FOR SOILS IN BERMUDA TEST PLOTS

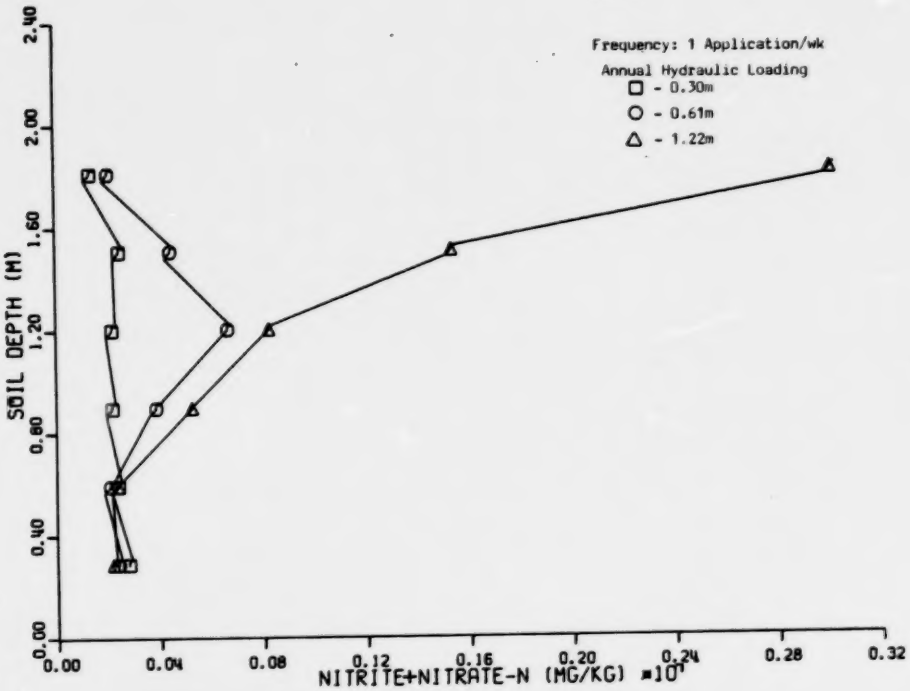
Soil Depth (cm)	Annual Hydraulic Loading (cm)											
	0.0				152.				198.			
	CEC		ESP		CEC		ESP		CEC		ESP	
	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983
30	17.	16.	0.6	0.6	17.	16.	1.8	6.3	17.	13.	2.9	7.6
61	20.	24.	2.5	2.1	26.	37.	1.9	1.9	32.	22.	1.6	4.1
91	33.	49.	2.1	1.4	34.	32.	2.1	1.9	32.	40.	2.5	1.8
122	31.	45.	1.9	1.3	25.	32.	2.0	2.2	29.	32.	2.1	2.2
152	30.	53.	1.6	0.9	26.	33.	1.9	2.1	28.	28.	2.2	2.5
183	33.	52.	1.8	1.0	32.	30.	1.6	2.0	33.	34.	1.8	2.1

	259.				305.				350.			
	CEC		ESP		CEC		ESP		CEC		ESP	
	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983	Feb 1983	Dec 1983
30	20.	16.	4.1	7.1	18.	20.	4.5	5.9	18.	25.	3.3	4.9
61	35.	30.	1.7	3.4	31.	37.	1.6	2.9	29.	32.	1.7	3.8
91	35.	30.	2.0	2.3	32.	34.	1.9	2.1	35.	33.	2.0	2.4
122	30.	25.	1.6	2.4	32.	40.	2.2	1.8	33.	35.	1.8	2.0
152	23.	31.	1.7	2.3	32.	30.	1.6	2.3	32.	39.	1.6	1.8
183	31.	37.	2.3	1.9	32.	36.	1.6	2.2	37.	34.	1.4	1.8

	396.			
	CEC		ESP	
	Feb 1983	Dec 1983	Feb 1983	Dec 1983
30	13.	16.	6.2	7.3
61	36.	52.	1.1	2.1
91	34.	74.	1.8	0.9
122	35.	60.	2.0	1.2
152	28.	65.	2.2	0.9
183	32.	65.	1.6	0.9

APPENDIX G

Supportive Figures for Trial 17000



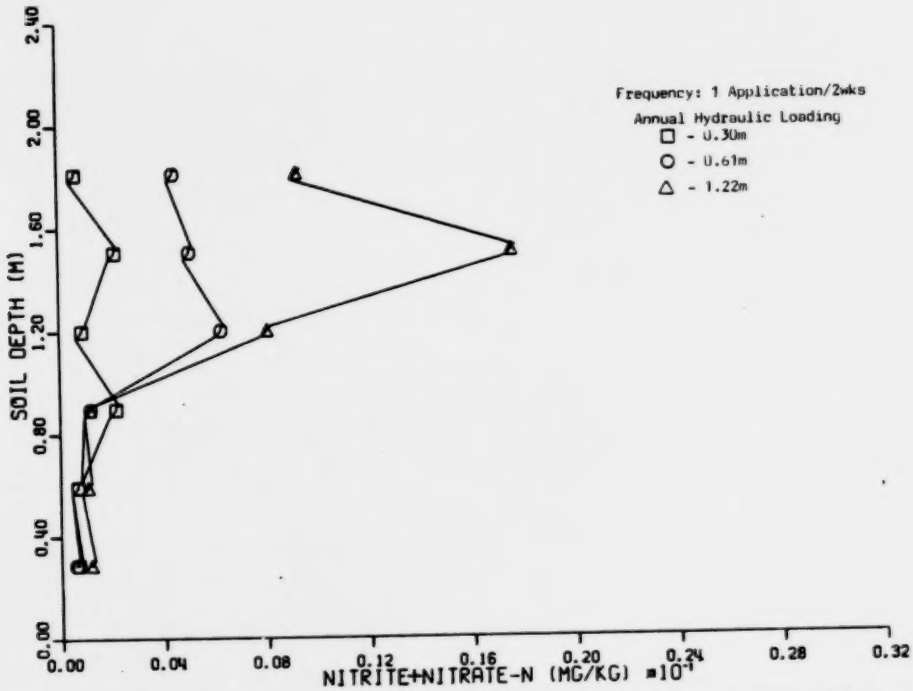
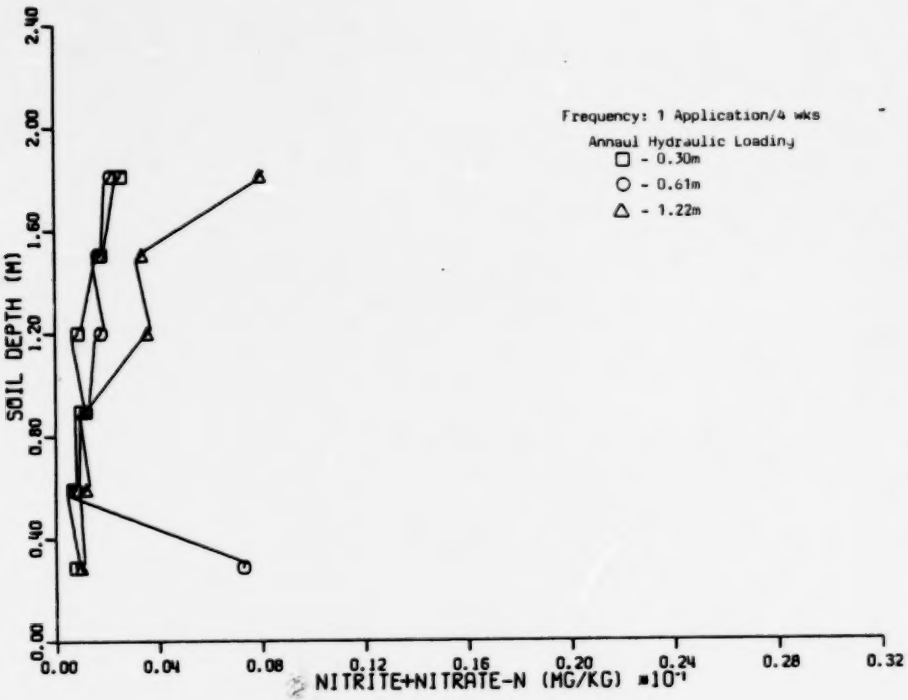


Figure G.5. Soil Nitrite plus Nitrate Concentrations in Trial 17000 Grain Sorghum Test Plots



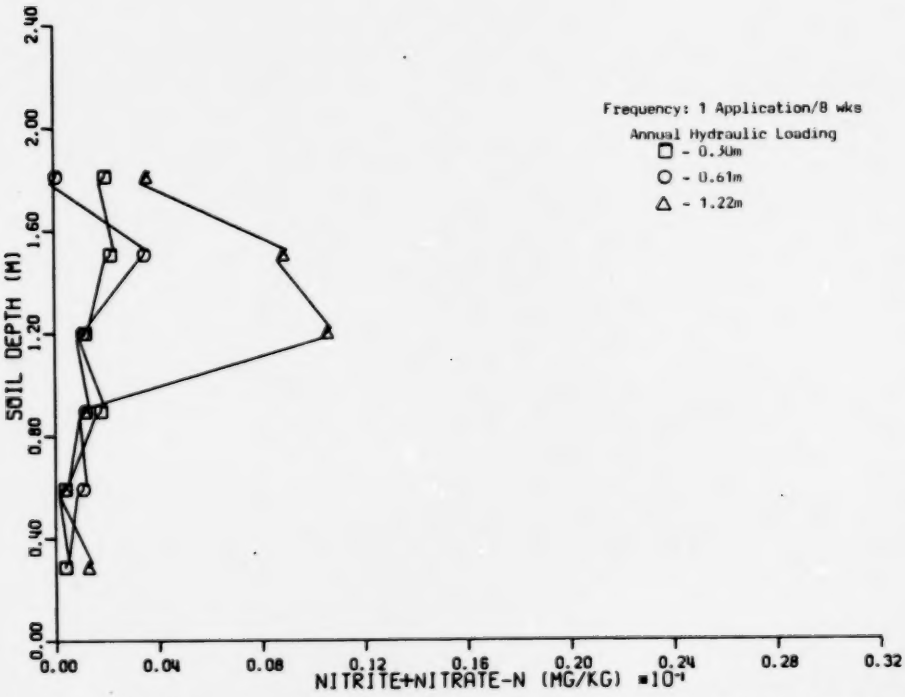
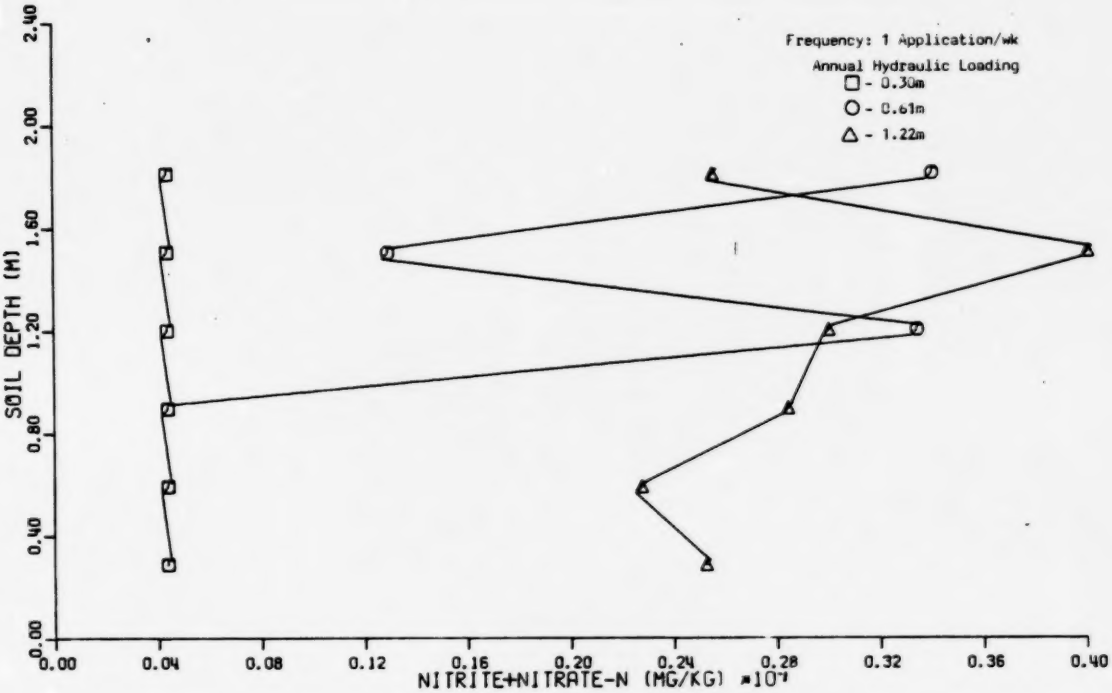


Figure G.6. Soil Nitrite plus Nitrate Concentrations in Trial 17000 Grain Sorghum Test Plots



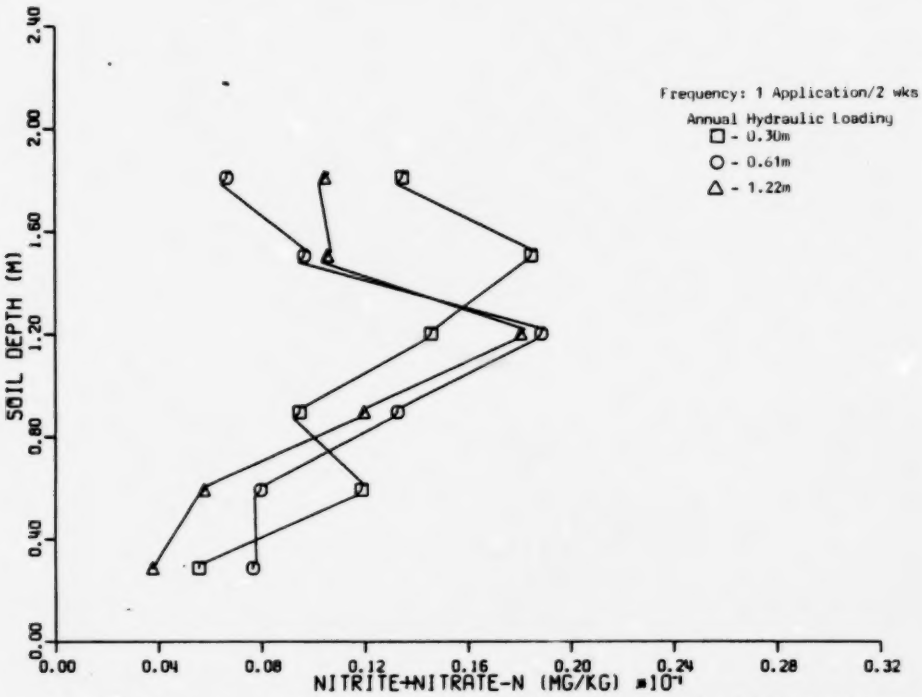
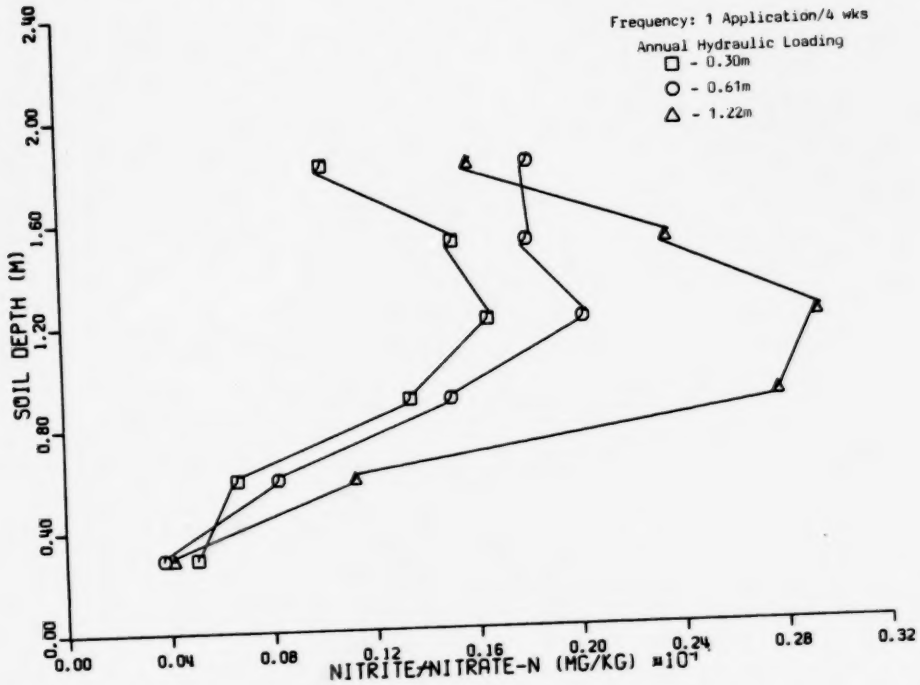


Figure G.7. Soil Nitrite plus Nitrate Concentrations in Trial 17000 Soybean Test Plots



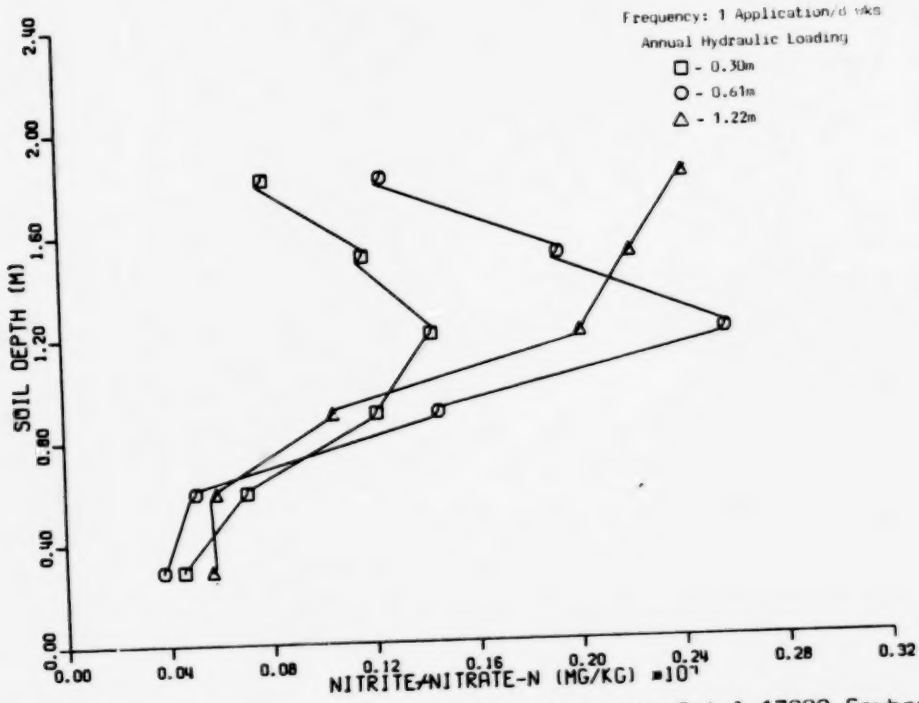


Figure G.8. Soil Nitrite plus Nitrate Concentrations in Trial 17000 Soybean Test Plots

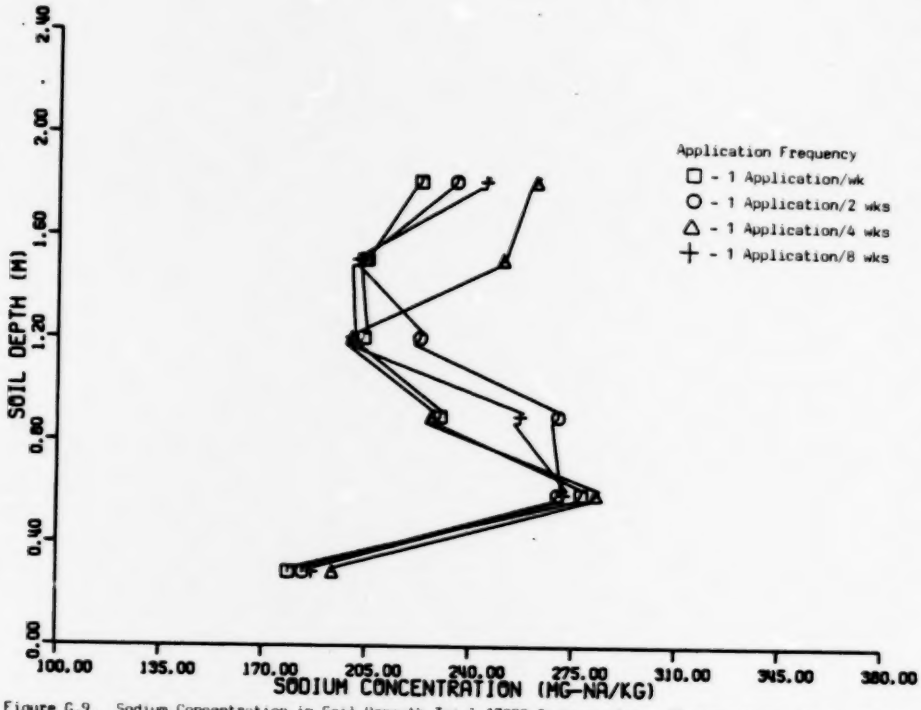


Figure G.9. Sodium Concentration in Soil Beneath Trial 17000 Soybean plots, 30 cm/yr Hydraulic Loadings

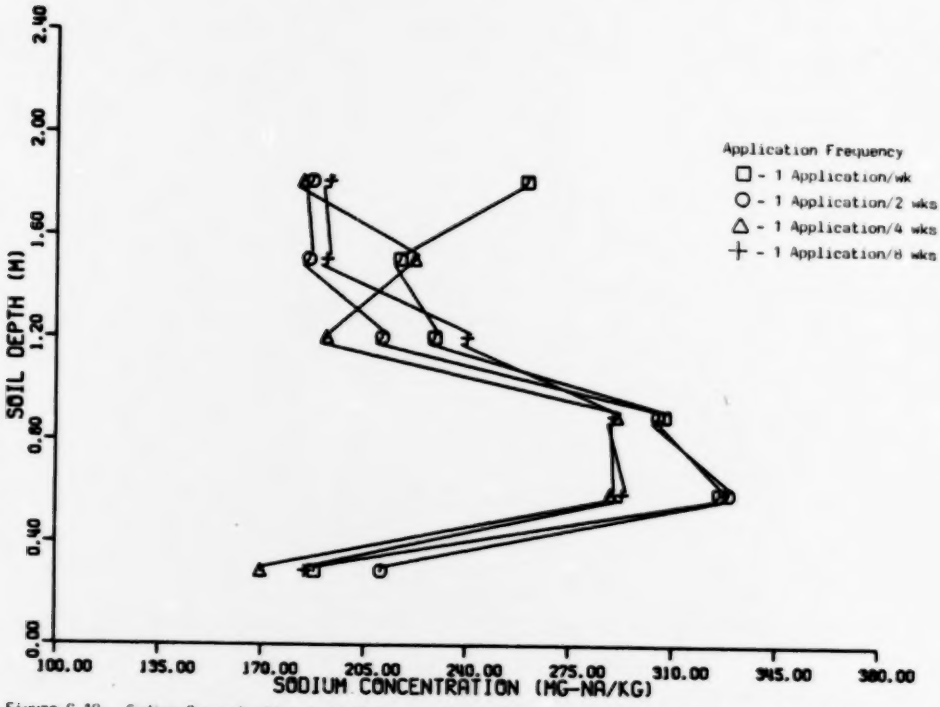


Figure G.10. Sodium Concentration in Soil Beneath Trial 17000 Soybean plots, 61 cm/yr Hydraulic Loading

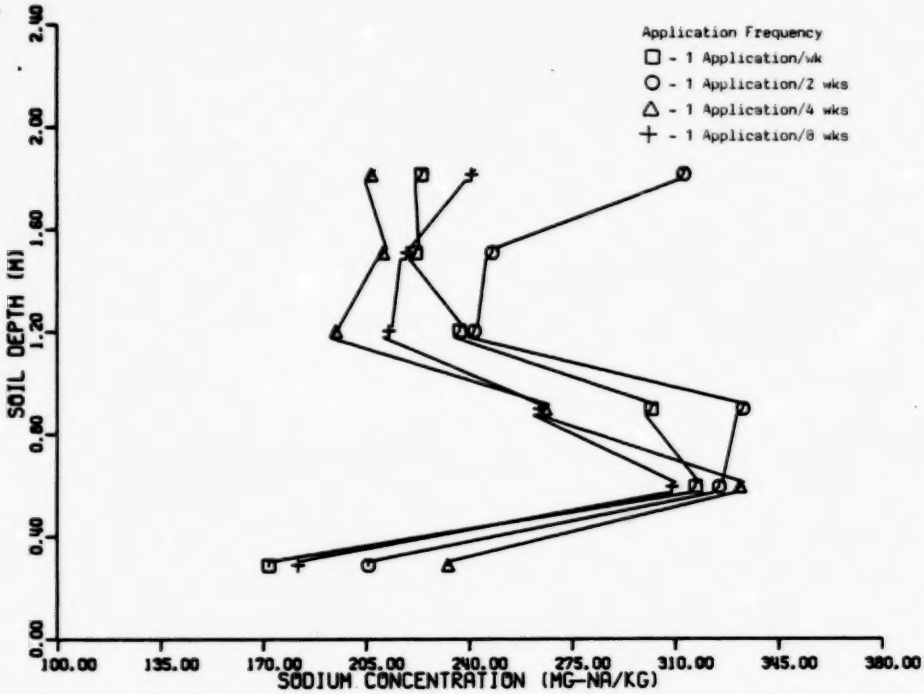


Figure G.11. Sodium Concentration in Soil Beneath Trial 17000 Soybean Plots, 122 cm/yr Hydraulic Loading

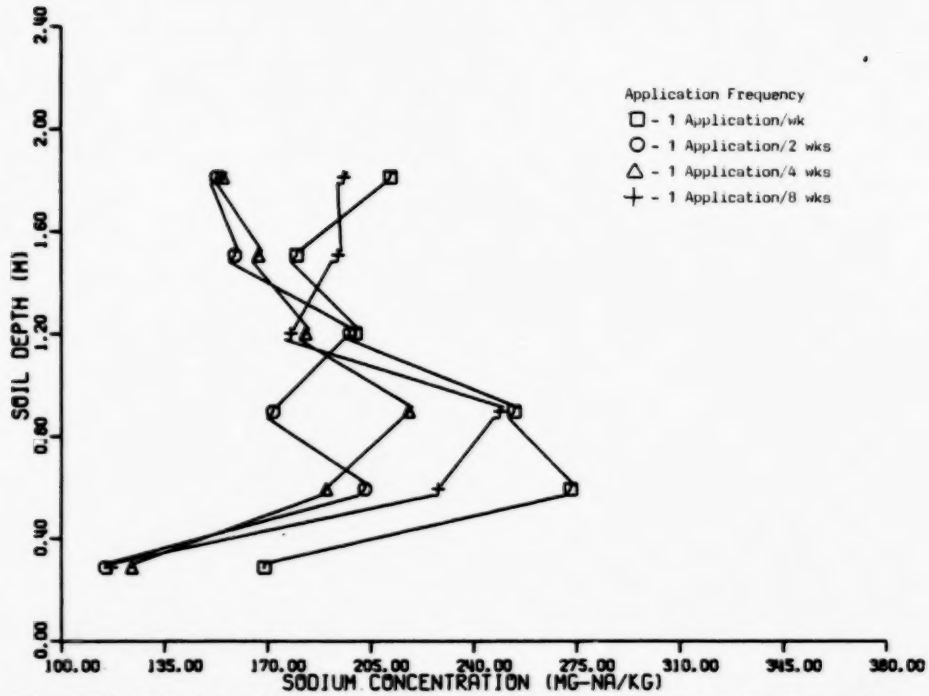


Figure G.12. Sodium Concentration in Soil Beneath Trial 17000 Grain Sorghum Plots, 30 cm/yr Hydraulic Loading

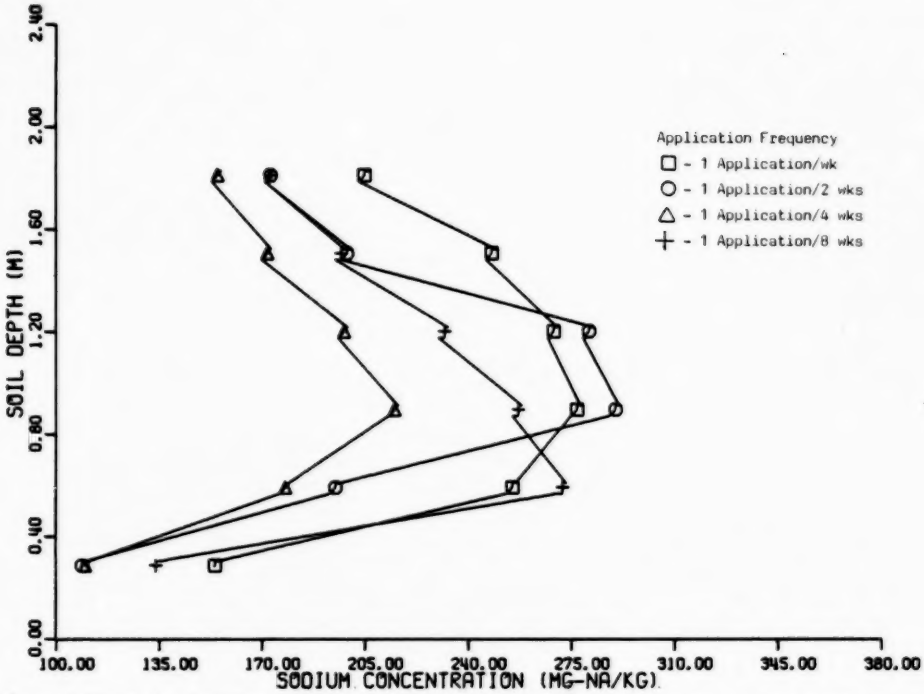


Figure G.13. Sodium Concentration in Soil Beneath Trial 17000 Grain Sorghum Plots, 61 cm/yr Hydraulic Loading

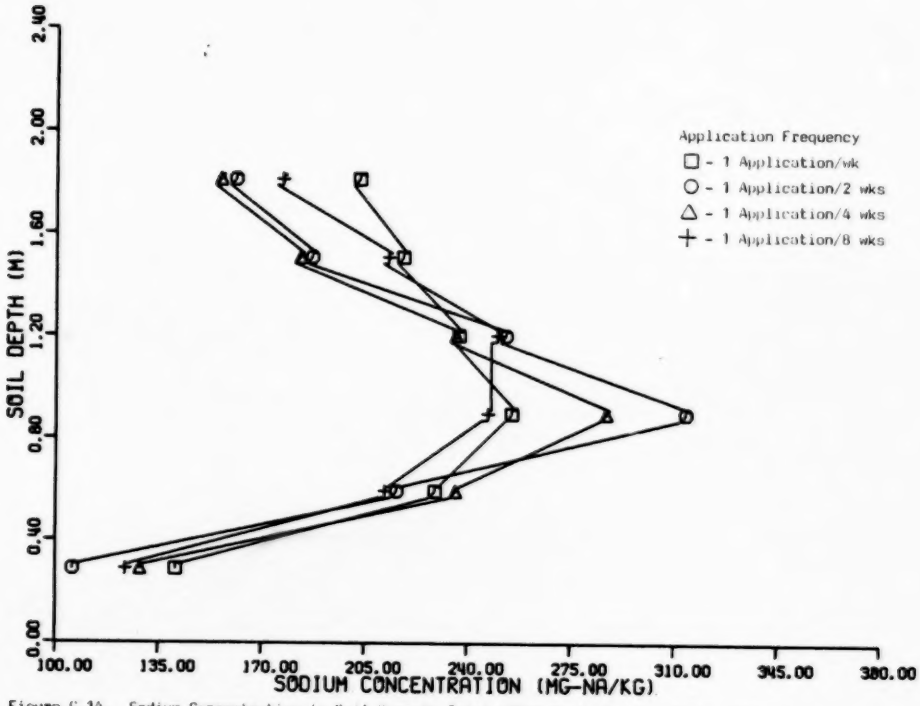
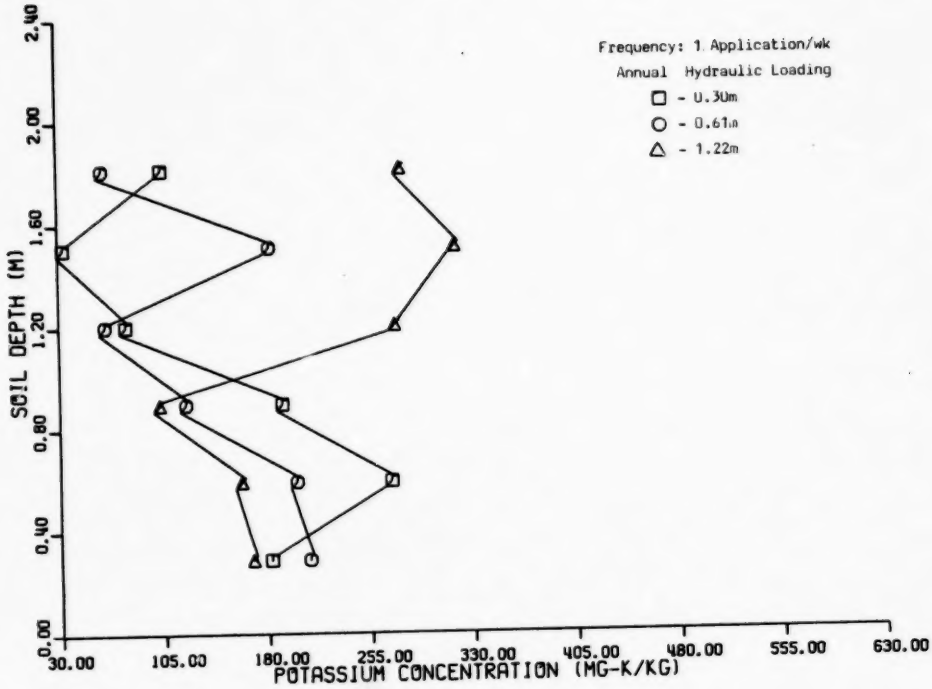


Figure G.14. Sodium Concentration in Soil Beneath Trial 17000 Grain Sorghum Plots, 122 cm/yr Hydraulic Loading



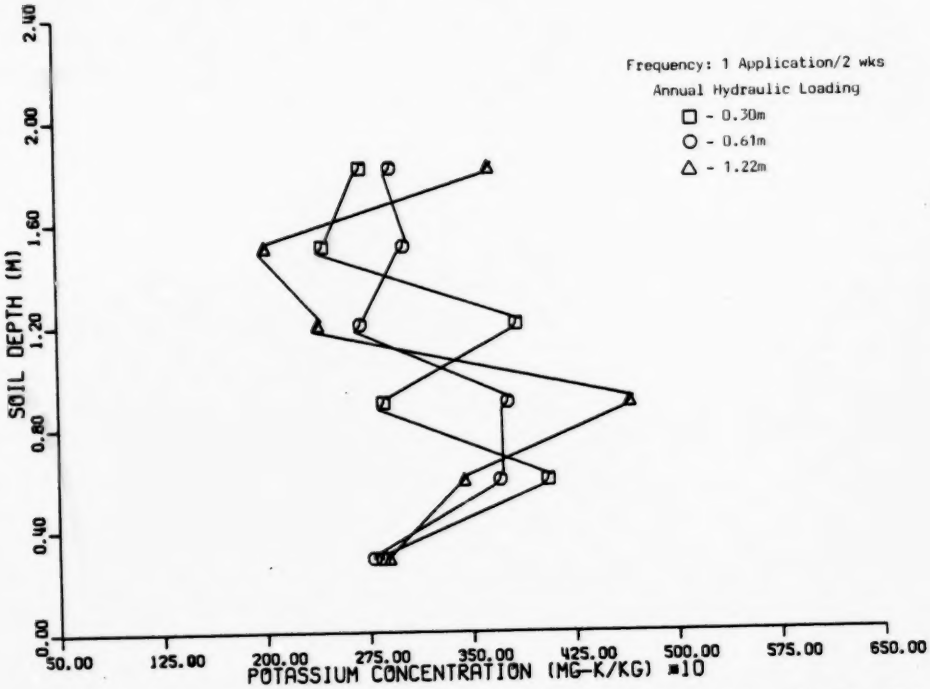
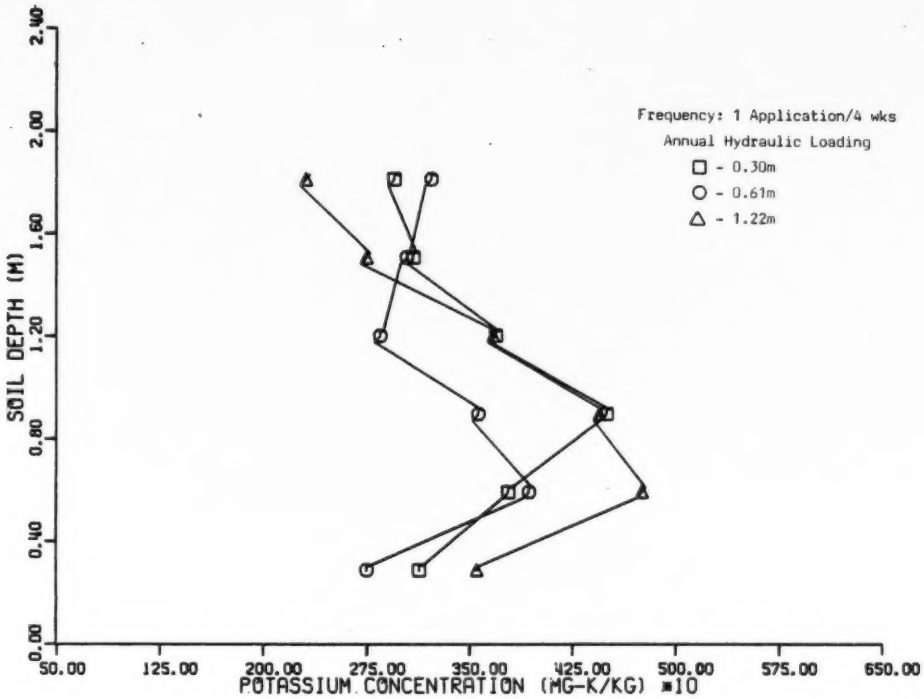


Figure G.15. Soil Potassium Concentrations in Grain Sorghum Plots, Trial 17000



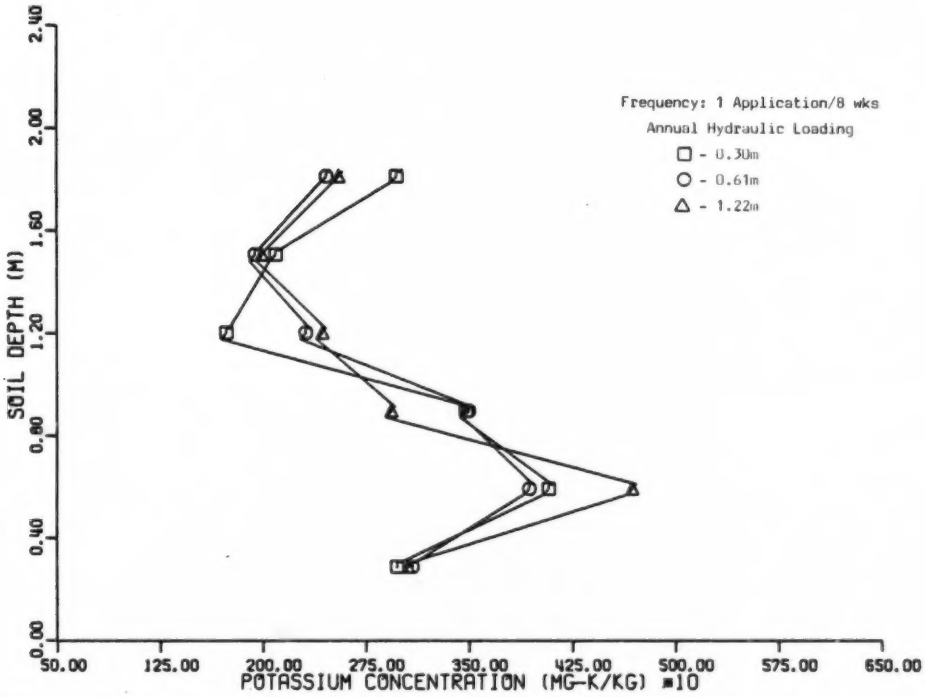
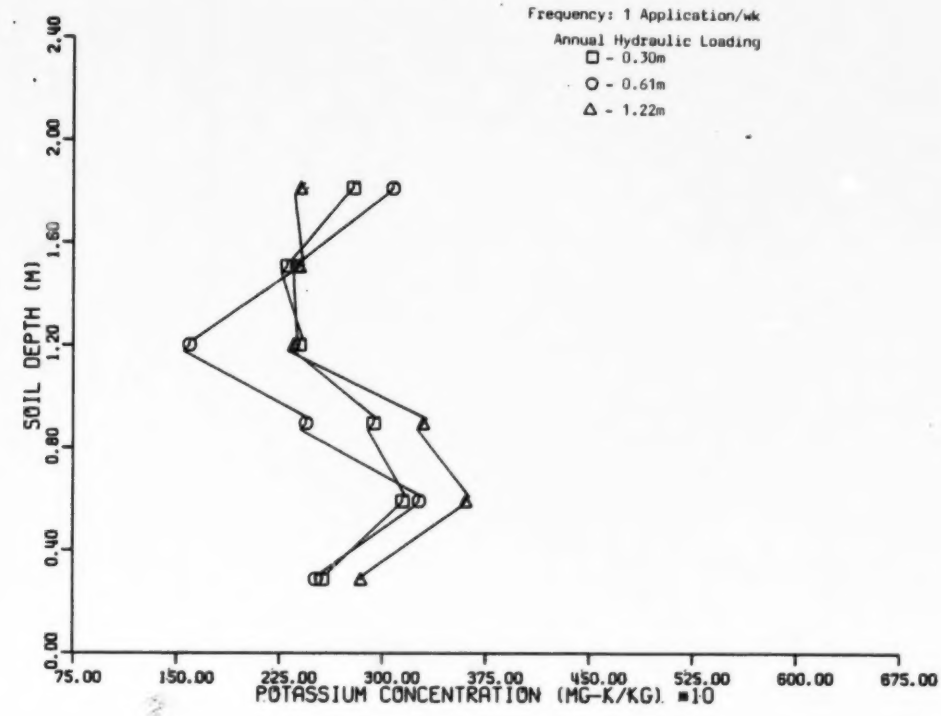


Figure G.16. Soil Potassium Concentrations in Grain Sorghum Plots, Trial 17000



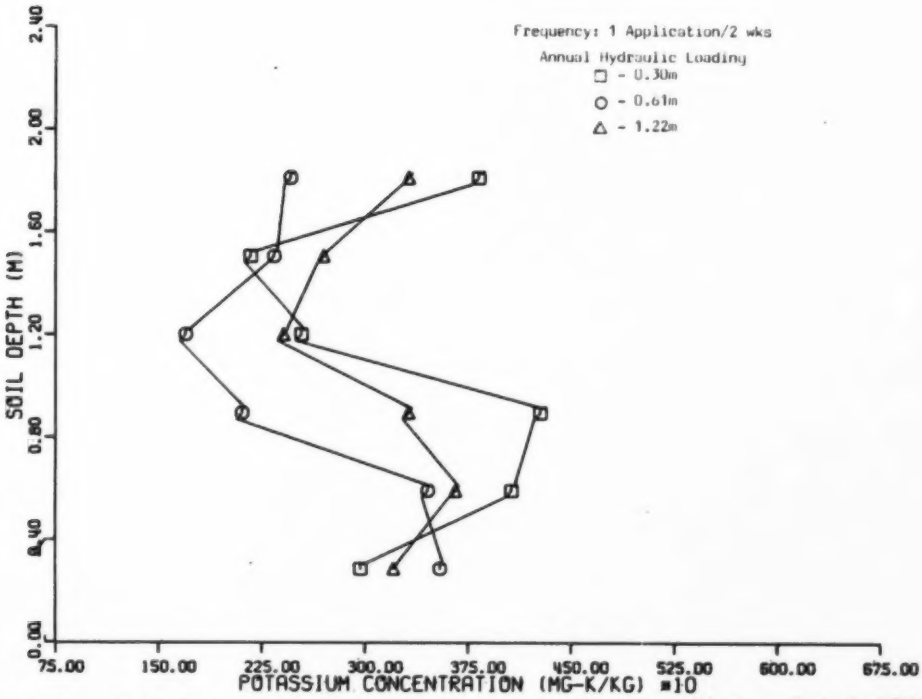
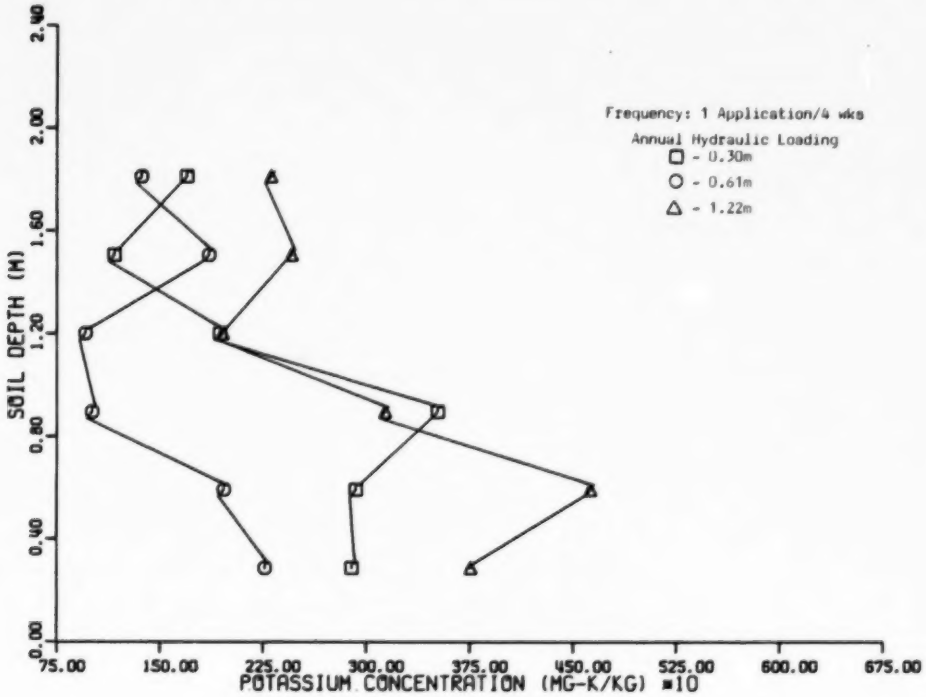


Figure G.17. Soil Potassium Concentrations in Soybean Plots, Trial 17000



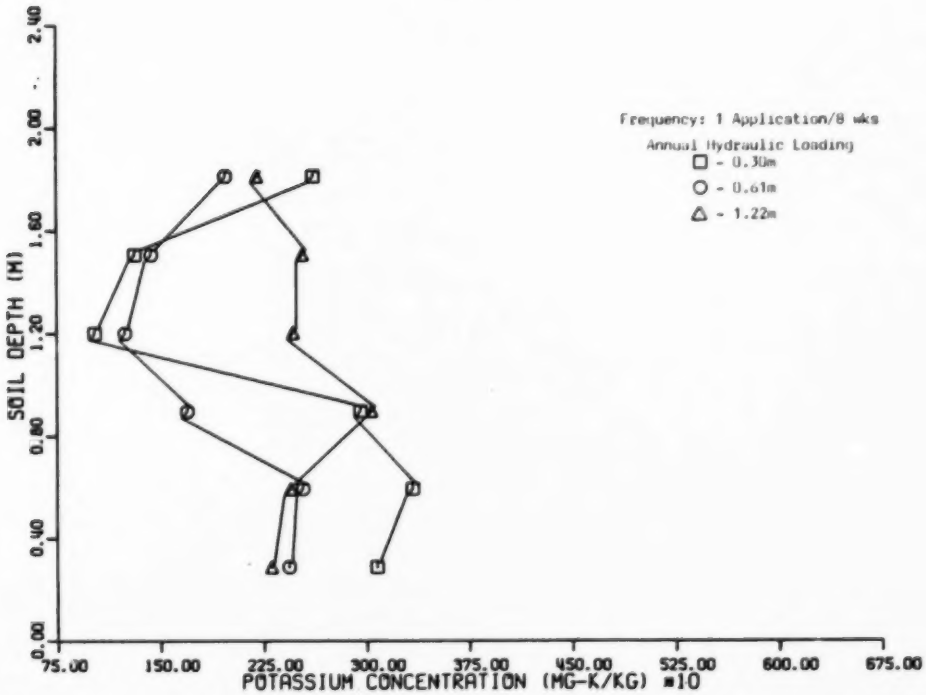


Figure G.18. Soil Potassium Concentrations in Soybean Plots, Trial 17000

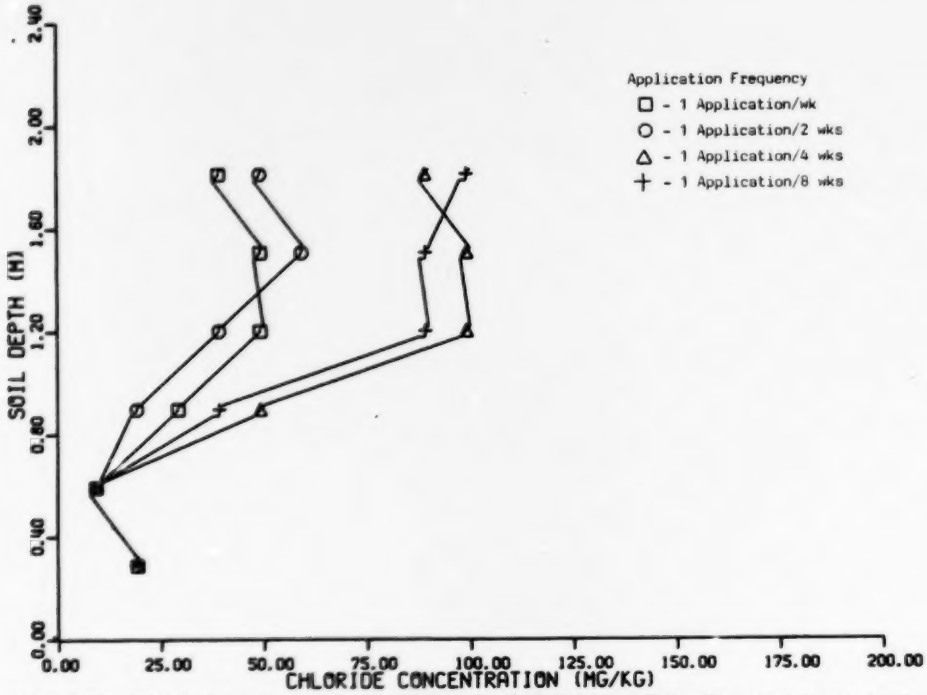


Figure G.19. Chloride Concentrations in Soil Beneath Trial 17000 Soybean Plots, 30 cm/yr Hydraulic Loading

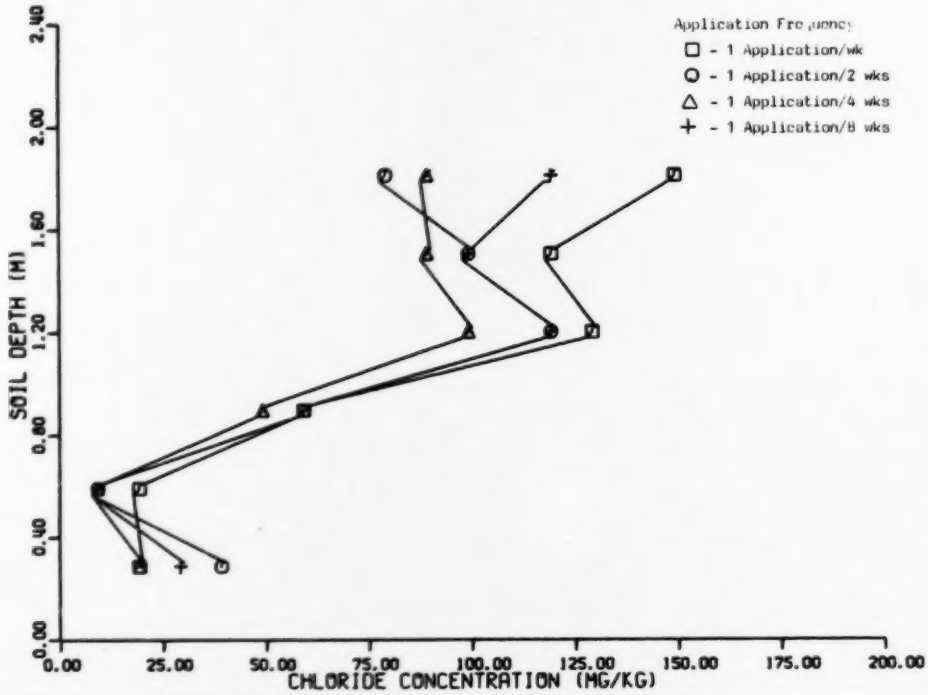


Figure G.20. Chloride Concentrations in Soil Beneath Trial 17000 Soybean Plots, 61 cm/yr Hydraulic Loading

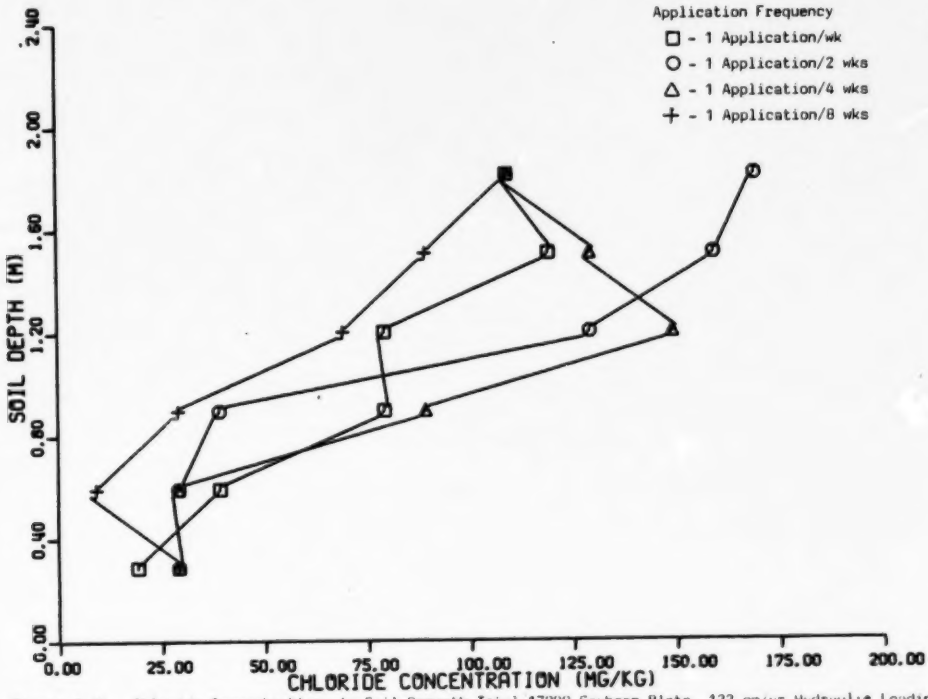


Figure G.21. Chloride Concentrations in Soil Beneath Trial 17000 Soybean Plots, 122 cm/yr Hydraulic Loading

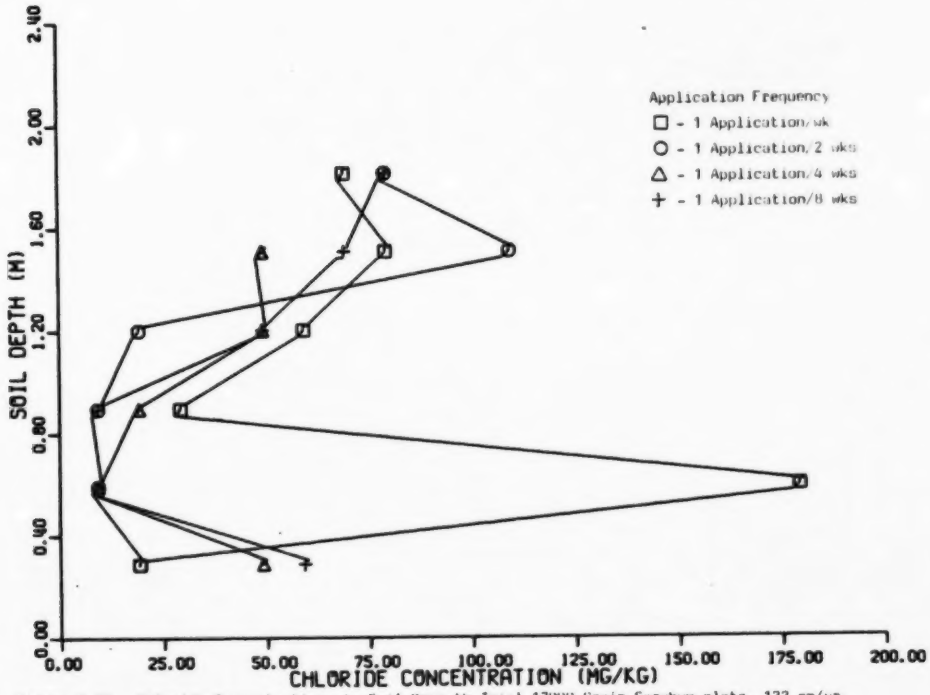


Figure G.22. Chloride Concentrations in Soil Beneath Trial 17000 Grain Sorghum plots, 122 cm/yr Hydraulic Loading

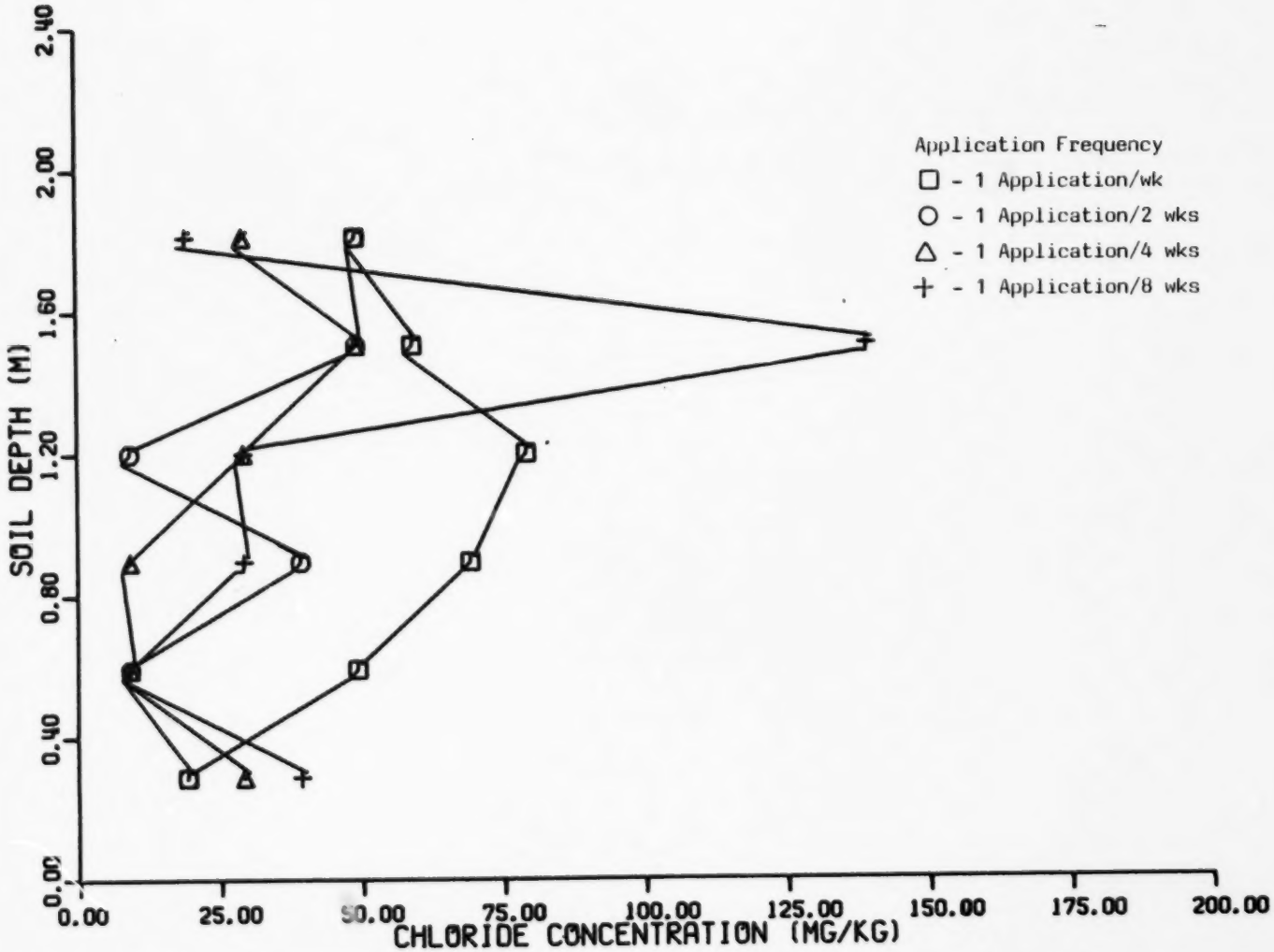


Figure G.23. Chloride Concentrations in Soil Beneath Trial 17000 Grain Sorghum plots, 30 cm/yr Hydraulic Loadings

APPENDIX H

Percent Moisture in Trial 17000 Soils

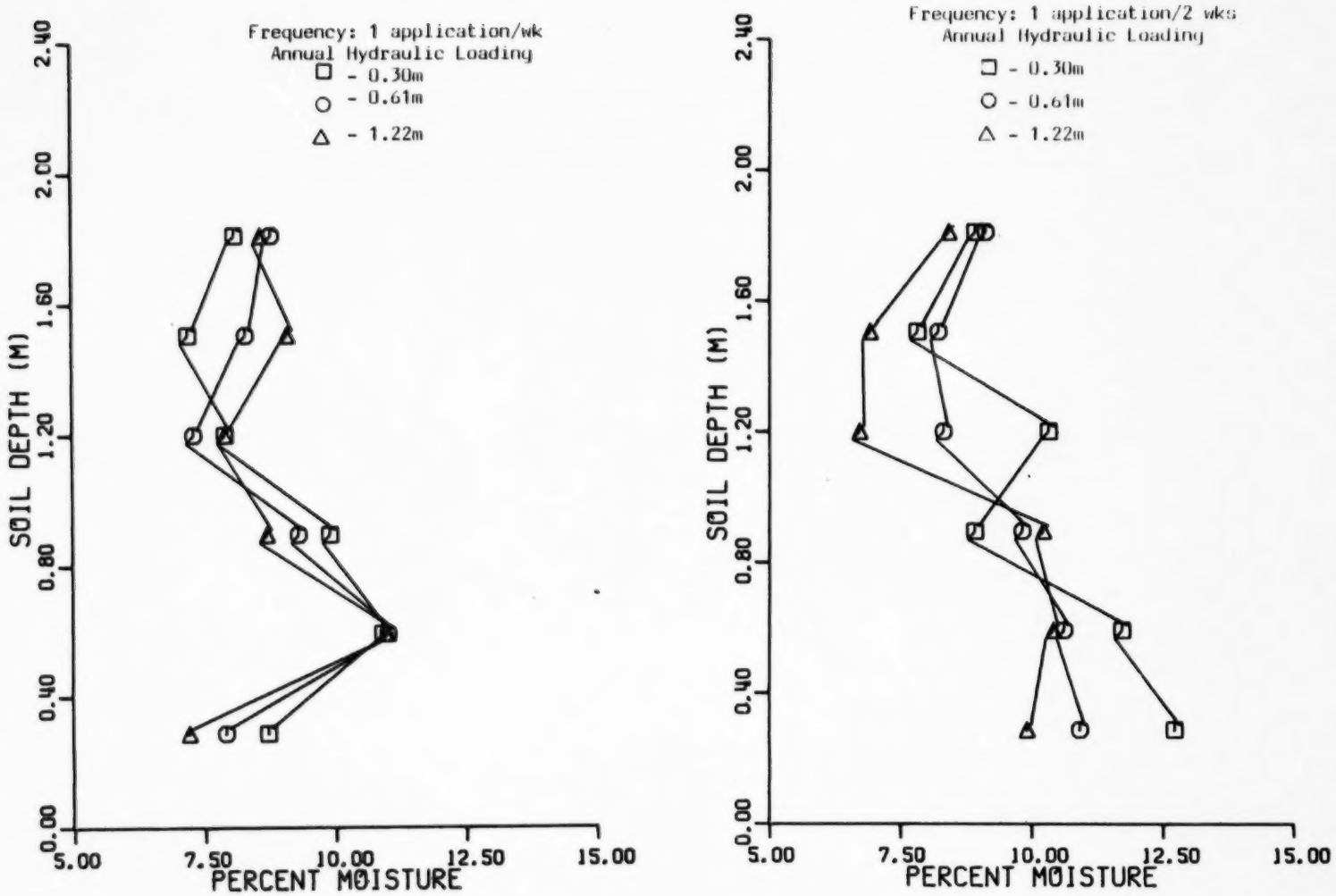


Figure H.1. Percent Moisture in Soil Beneath Trial 17000 Grain Sorghum (Milo) plots

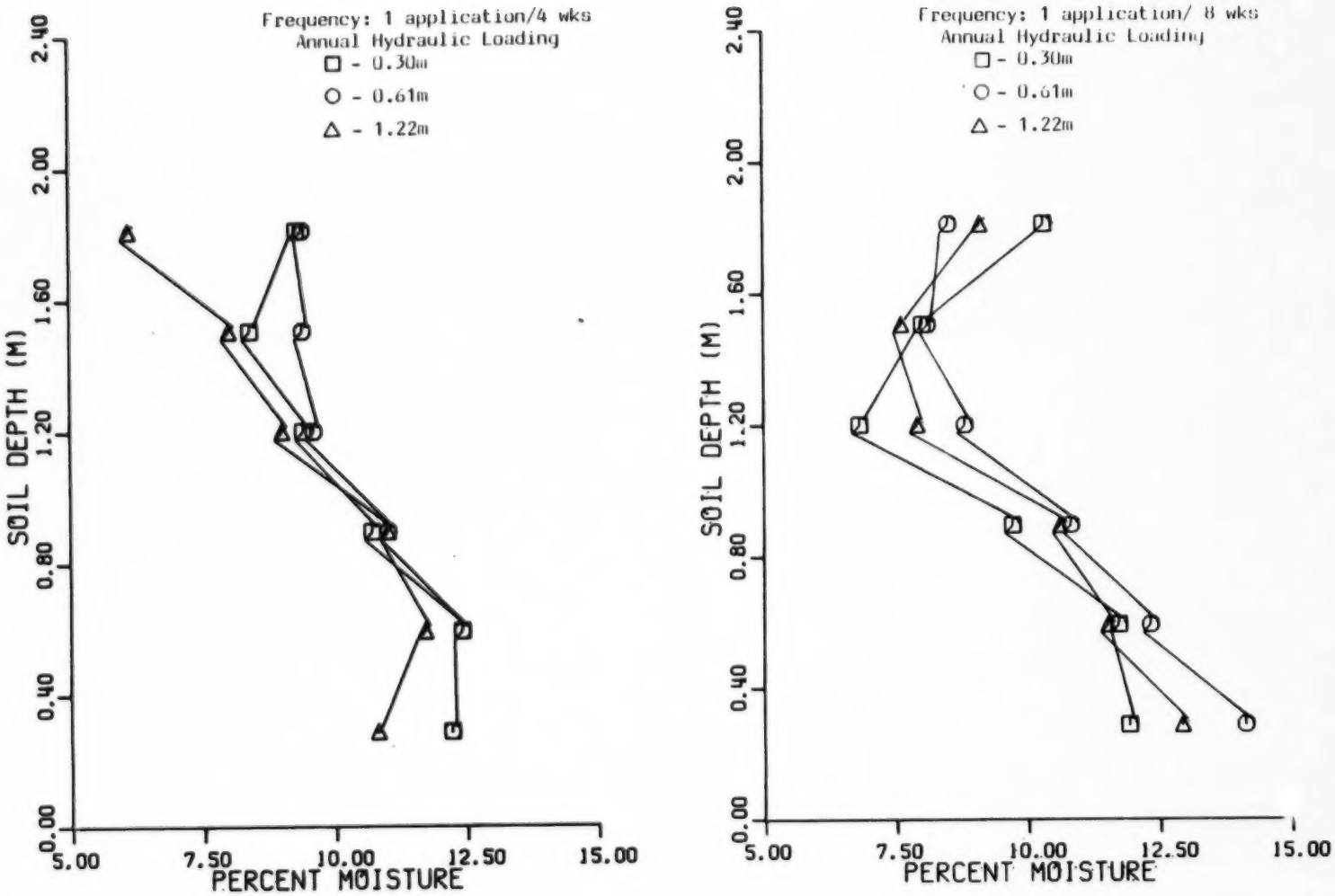


Figure H.2. Percent Moisture in Soil Beneath Trial 17000 Grain Sorghum (Milo) Plots

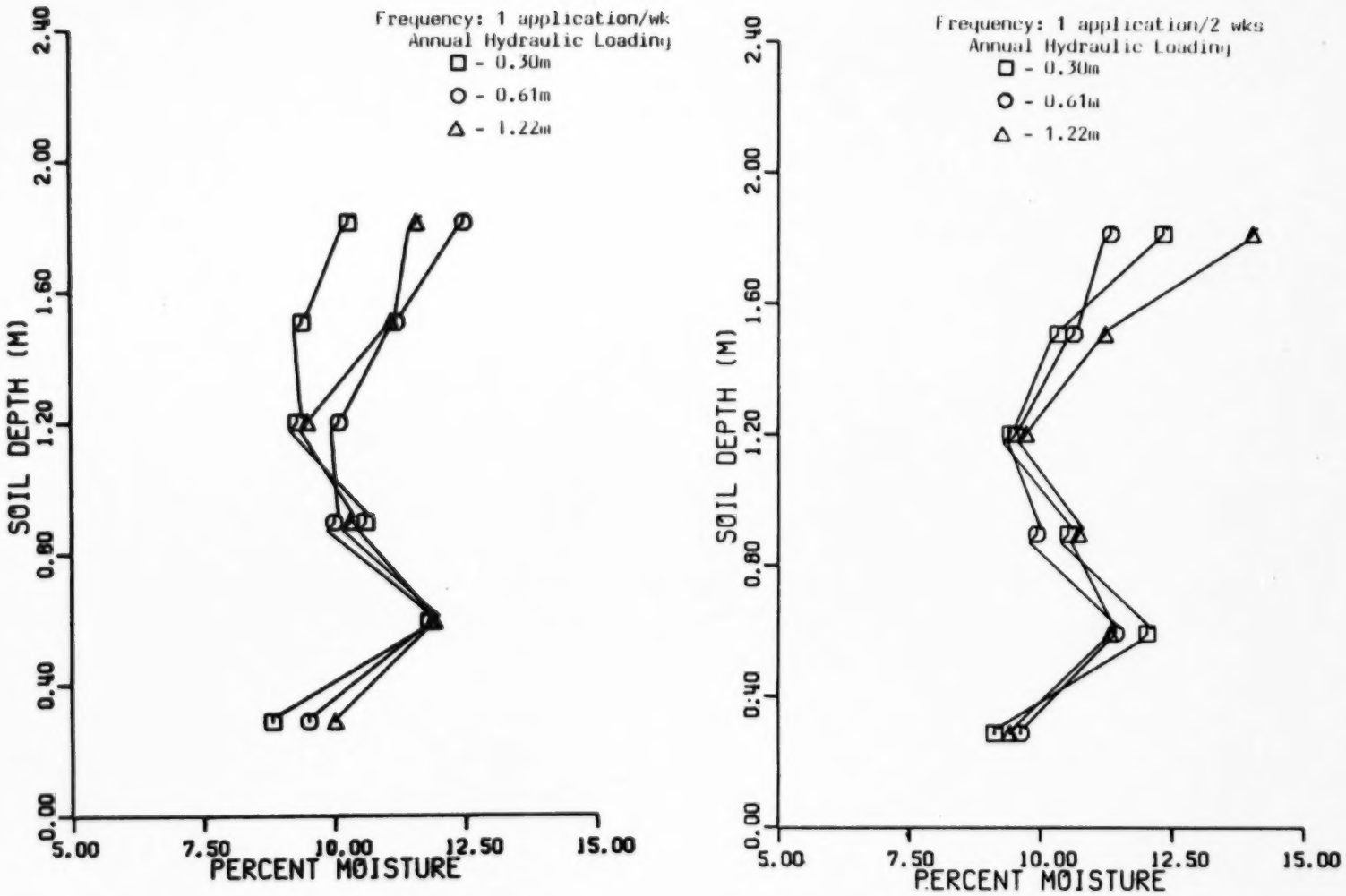


Figure H.3. Percent Moisture in Soil Beneath Trial 17000 Soybean Plots

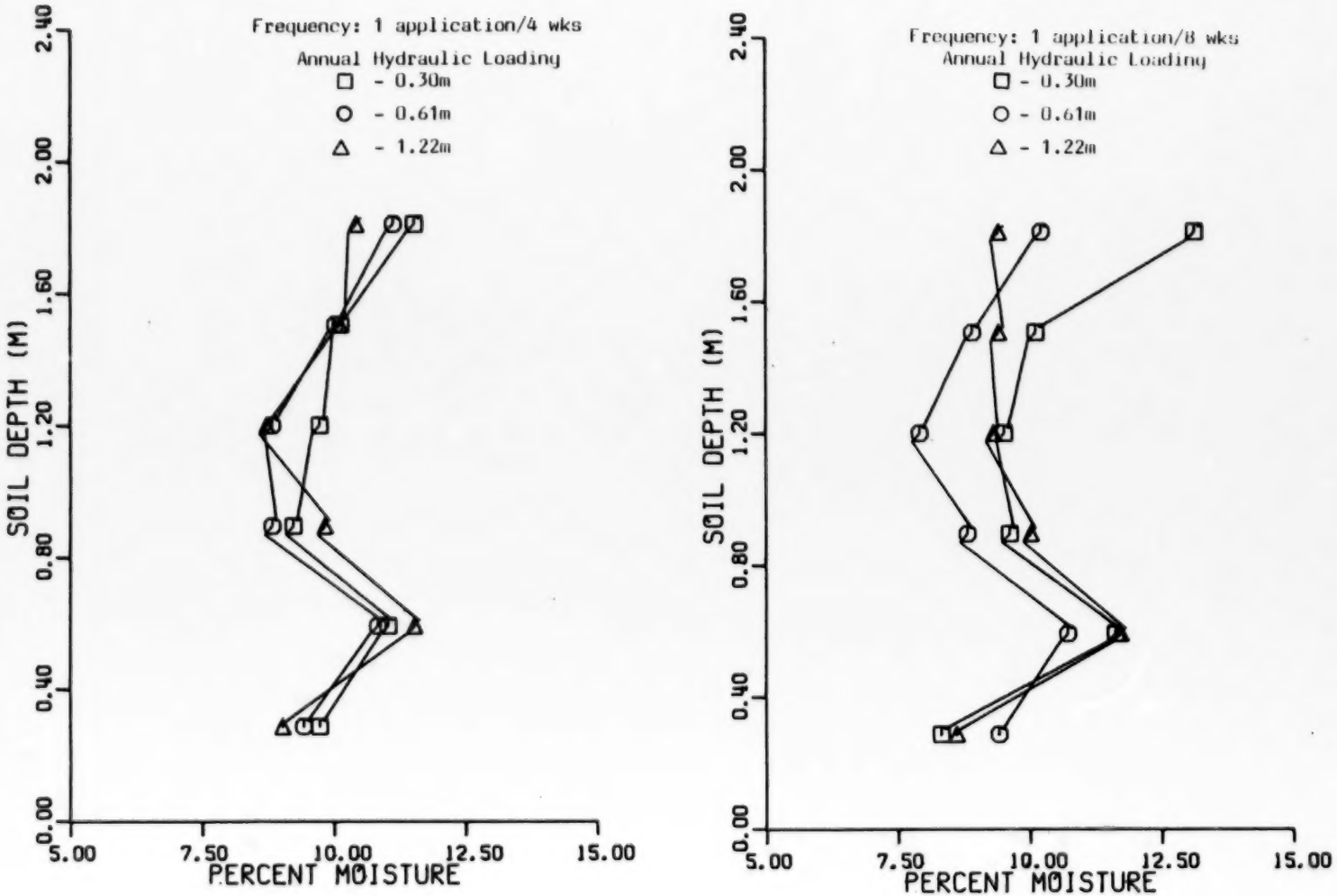


Figure H.4. Percent Moisture in Soil Beneath Trial 17000 Soybeans